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Ocean renewable energy in Southeast Asia: A review

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ABSTRACT

This paper presents preliminary research on ocean renewable energy (ORE) in Southeast Asia (SEA). It gives an overview of the ORE status of the region in terms of its potential and existing policies that support the utilization of ORE as an alternative source of energy. The study argues that there is potential to harness ORE in this region; however, there are a number of challenges to fully utilize this potential. This work presents (1) collated ORE resource information, (2) collated policies relevant to increase uptake in the region, and (3) an ORE development matrix which is important for analyzing the gaps in utilizing ORE in SEA. A review discussion on the unique conditions of SEA in terms of resource and ORE-relevant policies are tackled. Special attention is given to existing policy frameworks and regional non-economic barriers to see how these could impact the development of ORE in SEA.

Contents

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1. Southeast Asia and ocean renewable energy

Around the world, there has been an increasing search for "clean, socially acceptable methods of generating power" [1]. This is because of two interrelated factors: (1) the global demand for electricity, which is expected to increase in the next 20 years, and (2) the commitment of different countries to reduce their CO_2 emissions in the same time frame. Some of the efforts made and being made by countries to increase the share of renewable energy in their energy mix include the setting of feed-in-tariffs (FITs). While FITs are targeted at wind energy and solar energy, "the generation of electricity from waves, tidal currents and tides has received renewed interest." [1]

There are different forms of ocean energy – "tidal and currents, waves, salinity and thermal gradients" [4,5]. Tidal energy from the motion of tides can be harnessed for electrical energy [6]. The potential of tidal energy is dependent on the intensity of water level height ranges or tidal current velocities and thus, the greater intensity will yield higher electricity generation [7]. Kinetic and potential energy associated with ocean waves can be harnessed at onshore or offshore sites using different wave energy converter technologies [5,6]. Salinity gradient energy, as a result of fresh water mixing with seawater at the mouth of rivers, can be exploited by pressure-retarded reverse osmosis process and associated conversion technologies [5]. The temperature gradient between the sea surface and deep water can result in thermal energy, which can be harnessed using ocean thermal energy conversion (OTEC) processes as well [5].

It is noteworthy that the majority of ocean renewable energy-related installations are located in Europe and Canada. In recent years, China and South Korea have also been tapping the potential of their ocean renewable energy resources [8].

Ocean renewable energy (ORE) has tremendous global potential (shown on the top portion of Fig. 1). A number of ORE utilization and conversion technologies have reached pre-commercial stages (shown on the lower left of Fig. 1). Many wave and tidal energy conversion technologies have been developed since the past decade especially in Europe due to a huge drive to develop the marine renewable energy industry. The progress of each of the technologies classified per resource type has varied during the past years [8]. Tidal Barrages have been used commercially in France since 1966, in Canada since 1984, and in Korea since 2011. Tidal barrages can reach up to 80% energy conversion efficiency [8]. The conversion devices for Tidal In-Stream Energy (TISE), energy from tidal currents, have learned a lot from offshore wind and thus the rate of development has been somewhat accelerated the past decade. Water-to-Wire energy conversion efficiencies for tidal devices are typically from 25% to 40%. Wave energy technologies are a bit more spread out in terms of design (i.e. point absorbers, oscillating water column, shore-based, offshore, etc.). Thus, the cost estimates are also spread out (i.e. the uncertainty band is wide) (Lewis et al., [10–11] Si OCEAN). Ocean Thermal Energy Conversion (OTEC) is a technology that is relatively expensive in terms of capital cost but is somewhat more 'base load-appropriate' than wave or tidal when it comes to energy production. Salinity Gradient technologies are still in the early phases of technology demonstration and, to date, only low-end kW scales have been achieved but the development is accelerating [10,8]. The challenges of each technology type for harnessing ORE have been discussed in detail by Mueller and Wallace [12].

Although the estimates have begun to be more reliable and accurate this past few years, since the number of deployments have increased, there are still costs that can be shaved off especially those that pertain to support structures (cost contribution ~30% for wave and ~15% for tidal), installation (cost contribution ~5% for wave and ~25% for tidal), operation and maintenance (cost contribution ~15% for wave and ~20% for tidal) [11]. The levelized cost of energy (LCOE) for tidal systems range from ~32c/kW h to ~37c/kW h and for wave, the LCOE ranges from ~41c/kW h to ~52c/kW h (at 12% discount rate) [11].

The regional conditions in Southeast Asia such as "rapid economic growth, increasing energy demand, rising fossil fuel imports, growing environmental pressures, low rural electrification levels, and heavy reliance on fossil fuels and traditional biomass", as mentioned by International Energy Agency (IEA) [7], are favorable for renewable energy. Although natural energy resources vary significantly among Southeast Asian countries, the substantial amount of renewable energy available in the region is not much utilized yet [13]. One of the renewable energies that is relatively significant in the region is ocean renewable energy [14].

There are a number of on-going studies and activities that suggest the potential for utilization of ocean renewable energy in Southeast Asia (Fig. 2) [15–28]. This paper discusses the current status of ocean renewable energy in Southeast Asia. Specifically, it looks at the potential of ocean renewable energy and the existing policies related to ocean renewables in each country. This paper addresses the following questions:

(1) Is there really a potential for ocean renewable energy as an alternative source of energy in Southeast Asia?
(2) What are the challenges to the development and deployment of ocean renewable energy in the region?
(3) What efforts are being made by countries in Southeast Asia to increase the utilization of ocean renewable energy in the region?

This work makes use of both preliminary and secondary data in presenting the current status of ocean renewable energy in Southeast Asia. The data are collated from past and recent studies on ocean renewable energy in Southeast Asian countries. The authors also interviewed ocean renewable energy experts in the region for this study.

This work presents the review of each country's energy status (energy mix, growth, etc.), a review and summary of the ORE resource data in the region, a collation of renewable energy policies relevant to the uptake of ORE in SEA, and an ORE development matrix which is relevant to analyzing the gaps in utilizing ORE in Southeast Asia.

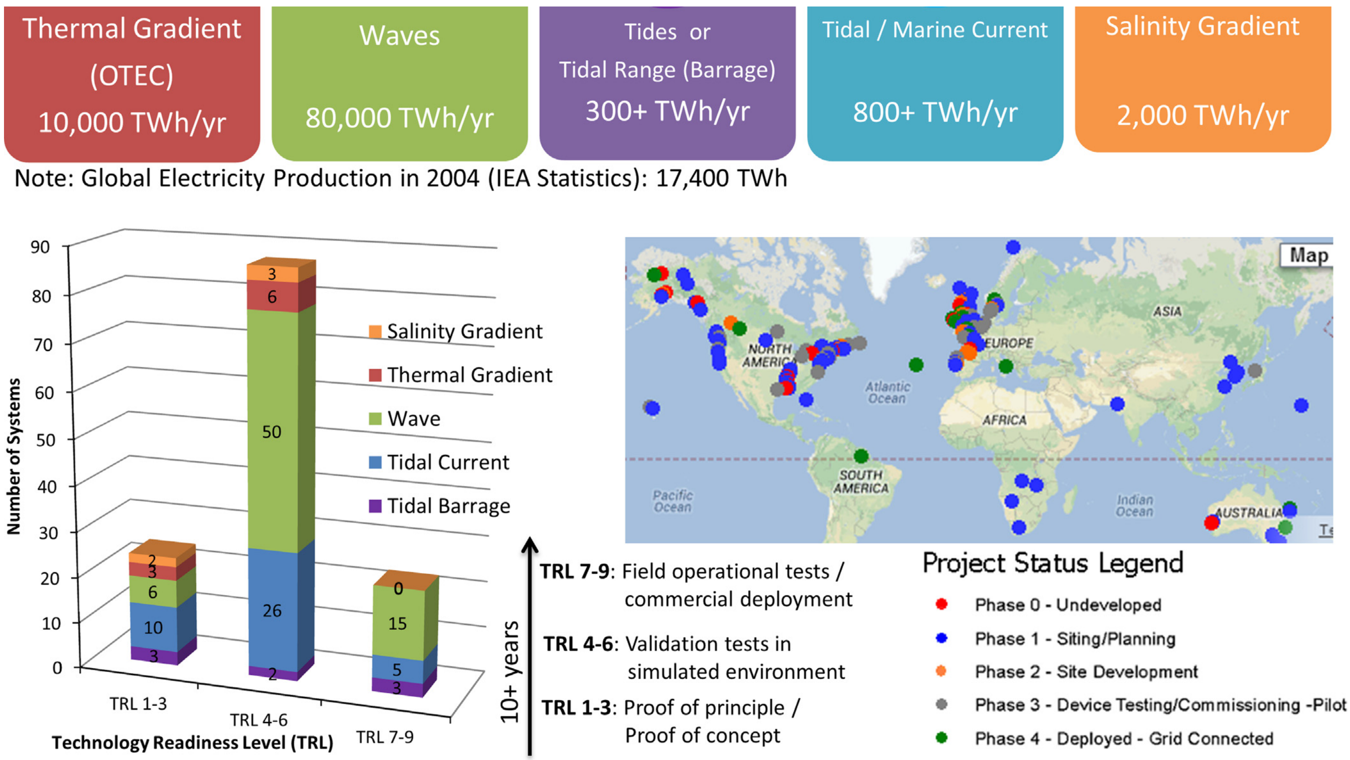


Fig. 1. Global Status of Ocean Renewable Energy: resource [2] (top), technology [3] (left) and projects [100] (right).

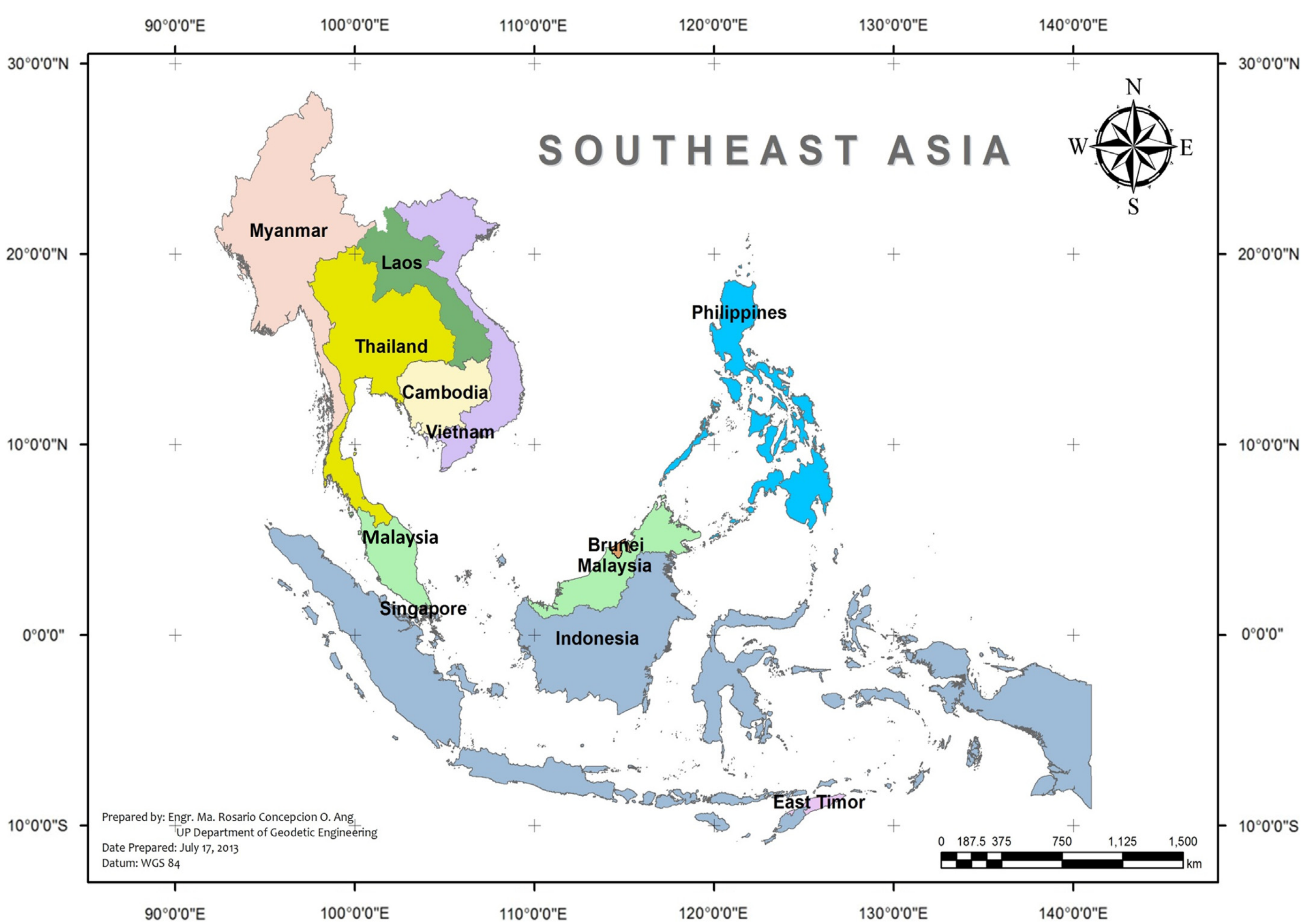


Fig. 2. Map of Southeast Asia region.

2. Overview of energy in Southeast Asia

According to analysts, the ASEAN region has an energy "trilemma" [29]. A study by National University of Singapore highlighted that "each member country needs to deliver on energy security, economic growth and development in an environmentally-sustainable way" [29]. Currently, a small portion of energy generated in the region comes from renewable energy while energy from fossil fuels occupies 74% of total energy mix [29]. The remaining energy mix consists of combustible biomass and waste (22%); geothermal (3%); and hydro (1%) [29]. Apart from energy from fossil fuels, the "traditional, inefficient and environmentally-unsustainable" biomass energy (such as firewood; charcoal) is having the second major share of total energy mix in ASEAN countries [13].

Fig. 3 shows the collated data regarding the reliance of different SEA countries to oil and gas as their primary source of energy. This figure is generated by the authors from different reports on energy mix by each Southeast Asian country. A collation of the individual energy mix of each SEA country is shown in Fig. 4.

Based from the data gathered, among the Southeast Asian countries, Brunei, Singapore and Malaysia are most dependent on energy from gas as their primary source. Brunei produces 163,000 barrels per day and is the third largest oil producer in Southeast Asia [30]. Similar to Malaysia, the energy mix of Singapore largely depends on electricity generation from natural gas [31]. In 2011, Malaysia's primary energy supply from natural gas stood at 35,740 ktoe [32].

In Cambodia, Indonesia, the Philippines and Thailand, the majority of the fuel mix is from oil. Although Cambodia heavily relies on imported electricity (41%), 54% of energy still comes from the heavy fuel oil [33]. The primary energy of Indonesia also comes from oil [34] followed by coal although interestingly, its energy mix includes renewable energy (such as hydro power). The Indonesian government has taken steps to promote the use of renewable energy which includes biomass, geothermal, solar Photovoltaics (PV), solar thermal and wind [34]. Oil is the largest fuel component in the Philippines' energy mix. However, similar to Indonesia, renewable energy forms a substantial portion of Philippines' energy mix. The combined share of renewable (geothermal, biomass, solar and wind) was around 41% in 2011 [35]. Thailand's primary energy supply is mostly from fossil fuels, oil and natural gas and they are the second largest oil importer in Southeast Asia behind Singapore [36].

Vietnam, Laos and Myanmar's main source electricity varies from the rest of the Southeast Asian countries [37–39]. Biomass takes up majority of their energy mixes. Vietnam's biomass is almost 1/3 of its energy supply [39]. As for Lao PDR, 61.4% of its energy mix is from "other" energy which is mainly biomass [37]. Among the countries in the region, Myanmar is the least dependent on oil and gas. 69.9% of its primary energy supply is from biomass like fuel wood, agricultural waste and charcoal. 18.2% is from natural gas, and 8.5% is from oil. Coal and hydropower has a small share of 0.9% and 2.4%, respectively [38].

Although most of the Southeast Asian countries area still dependent on traditional sources of energy which are oil and gas, the region is "waking up to the potential of renewable energy and energy efficiency" [40]. SEA countries have rich potential in geothermal, wind and solar energy. Being surrounded by bodies of water, the region is also being studied to assess the utilization of ocean renewable energy as its alternative source of energy. Aside from the region's geographical location, a number of private firms are interested to invest in renewable energy, which could mitigate climate change by reducing greenhouse gas emissions [41]. Government policies throughout the region are increasingly favoring renewable energy and the environment [40]; although some factors are still be taken into consideration to maximize its full potential in the region.

3. Ocean renewable energy potential in resource in the Southeast Asian region

This section presents collated data from various sources concerning the ORE resource of SEA. Most of the Southeast Asian countries have data available to be studied and analyzed for ocean renewable energy (except for *Lao PDR* as it is a land-locked country.)

3.1. Brunei Darussalam

In 2011, Malik [18] surveyed potential renewable energy sources for Brunei including solar, wind, ocean and biomass. He concluded that although there is potential for wave energy, it may not be economically viable. Brunei is seen to still rely on fossil

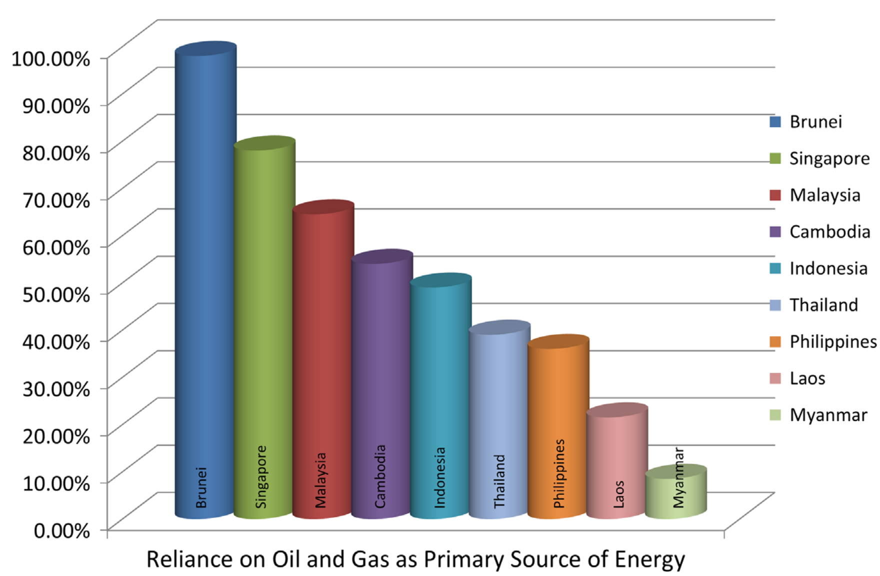


Fig. 3. Collated data on SEA countries Reliance on oil and gas.

fuels until 2030 because alternative sources of energy have not been able to address the high demand [42].

3.2. Cambodia

Based on the gathered data, Cambodia's annual tidal range is not suitable for commercial tidal energy extraction at present [33].

3.3. Indonesia

Like Malaysia, Indonesia has conducted a series of studies on its ocean renewable energy potential. According to Indonesian Ocean Energy Resources ratified by the Indonesian Ocean Energy Association (INOCEAN), theoretically, there is a resource of 57 GW for OTEC, 160 GW for tidal current and 510 GW for ocean wave [43]. In practice, there is 43 GW for OTEC, 4.8 GW potential for tidal, and 1.2 GW for ocean. INOCEAN has identified suitable sites for tidal, wave and ocean thermal, as well as provided the estimates mentioned above. The Fig. 5 shows the potential sites as identified by INOCEAN [43].

As for tidal-in-stream energy resources in Alas Strait in Indonesia, the total extractable energy is 329.299 GW h per yr at water depth ranges from 24 to 40 m, with peak flow rates of around 2 m/s. With the future floating marine current turbine (MCT) scenario, the tidal turbine arrays at water depth ranges from 8 to 24 m, yield the total tidal energy potential of 641.622 GW h per yr [44,45].

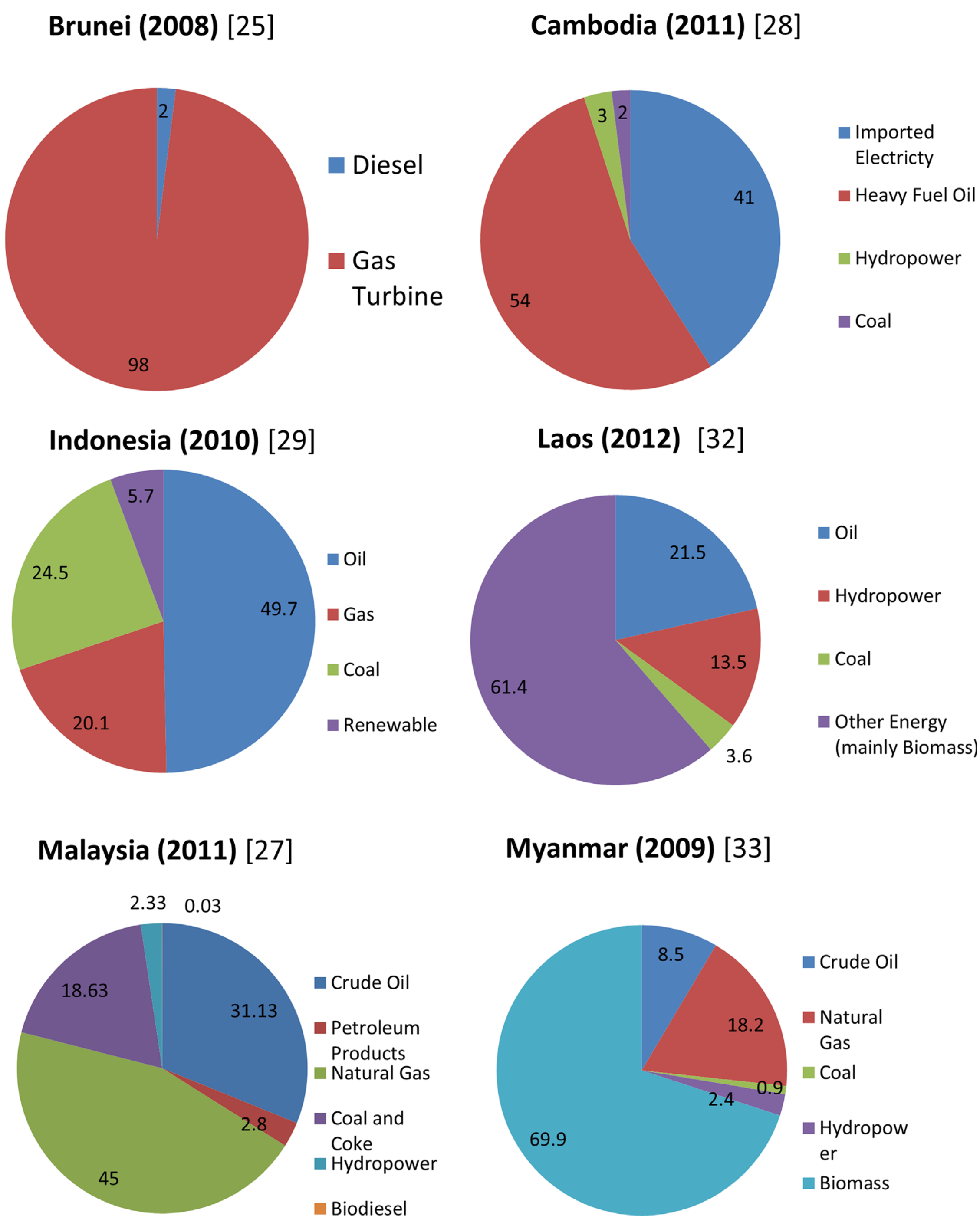


Fig. 4. Energy mix per Southeast Asian Country.

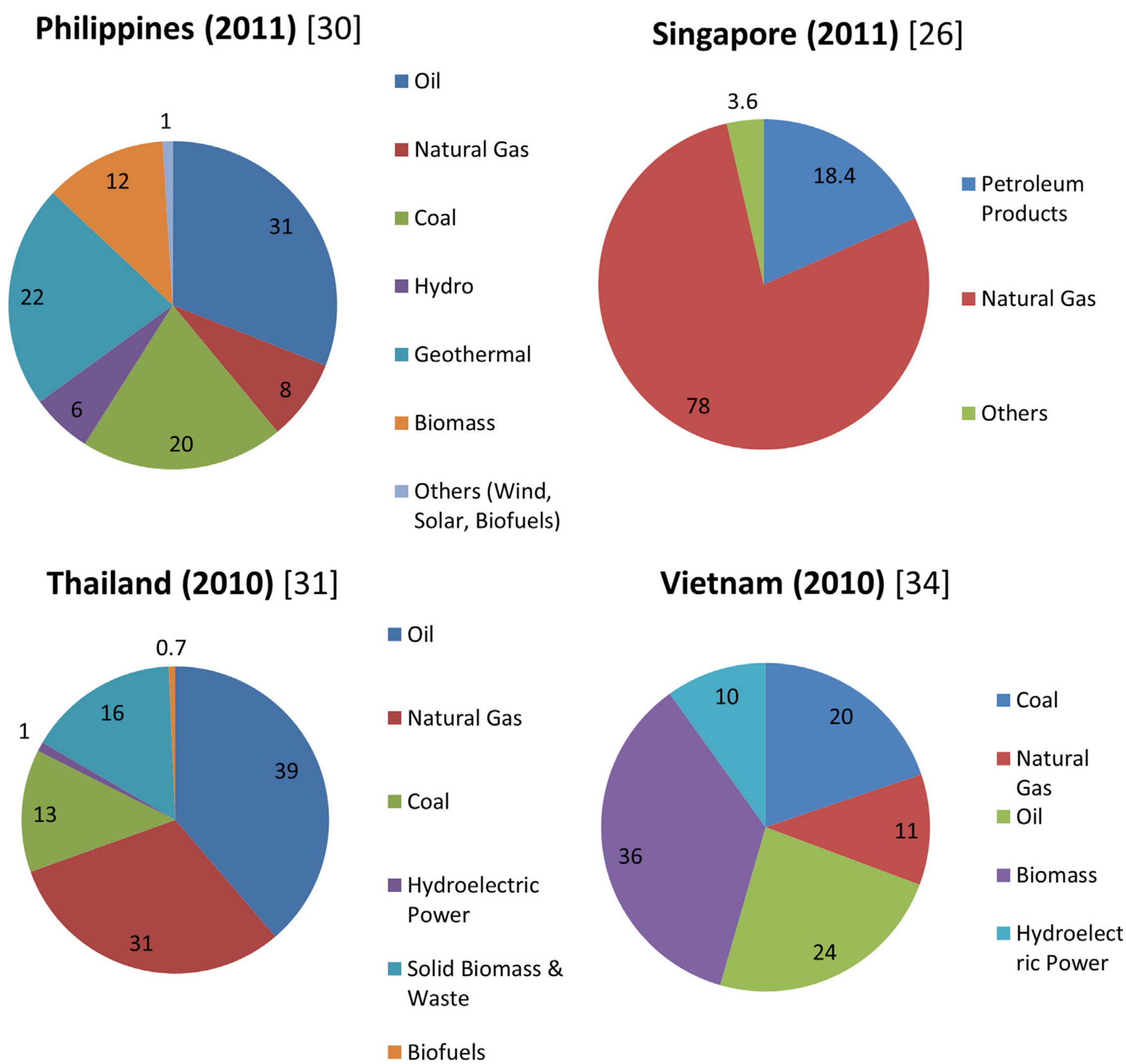


Fig. 4. (*continued*)

Indonesia's coastline is estimated to have potential ocean energy of 10–35 MW per kilometer. Currently, the ocean current system in the Lombok Strait is one demonstration project that has been developed for ORE in the country [46].

3.4. Malaysia

Malaysia has intensive studies on ocean renewables. In 2006, Yaakob, et al [19] analyzed existing oceanographic data for Malaysia and determined the potential and suitability of ocean thermal energy, tidal energy, wave energy, marine current and salinity gradient. Upon considering the existing models, they concluded that Malaysia has less potential for ocean-derived renewable energy as compared to other locations. Fig. 6 describes the ocean wave in Malaysia. It shows low waves which height averages at 1 m.

Mirzaei et al. [47] has studied the wave energy potential along the east coast of Peninsular Malaysia and the findings showed that the annual average wave power for selected sites in the northern section of the coast is between 2.6 and 4.6 kW/m and those of the southern section range between 0.5 and 1.5 kW/m. This corresponds to the waves with significant wave height between 1 and 3 m and wave period of 6–9 s for the northern section and the southern section of the coast having significant wave height of 1–2 m and wave period of 7–9 s respectively [47].

However, in 2010, Lim and Koh [21] has identified potential sites for tidal energy extraction which were expected to generate 14.5 GW h/yr. In Sabah, tidal energy potential was estimated at 8188 GW h/yr from Kota Belud and 386 GW h/yr from Sibu. This is a small fraction of the energy demand but it still poses a possible solution to the energy shortage [48]. The Malaysian western coastline has access to the Straits of Malacca which has a great potential for marine renewable energy extraction because of its average tidal current speed of 2 m/s (4 knots) [49].

In fact, Universiti Teknologi Malaysia (UTM) has recently launched an OTEC Centre based in Kuala Lumpur but it would be eyeing Sabah as a field of its research and study. 1200 m depth is found within 125 km distance from the shore and the bottom temperature is about 4 °C at 1200 m water depth [20].

3.5. Myanmar

No extensive studies on the ocean renewable energy resources have been done in Myanmar yet. However, Myanmar has several sites having some of the largest tidal range in Southeast Asian Region, with semi-diurnal tides of 5–7 m range suitable for economic electricity generation [50]. For instance, Elephant Point on the Gulf of Martaban has mean high water spring tides of 6.6 m and can be estimated to yield 4.9 W/m^2 energy potential, by using

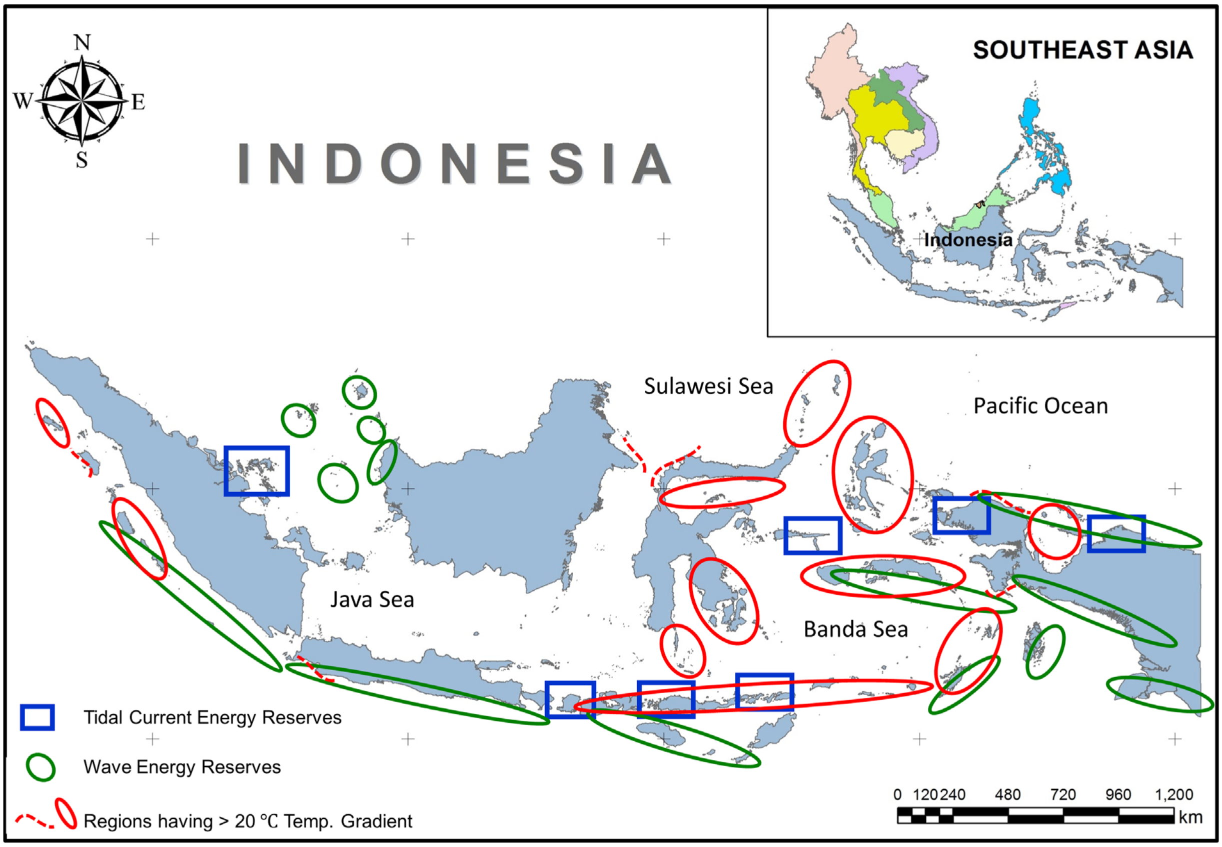


Fig. 5. Potential tidal, wave and OTEC Energy Sites in Indonesia (INOCEAN) [43].

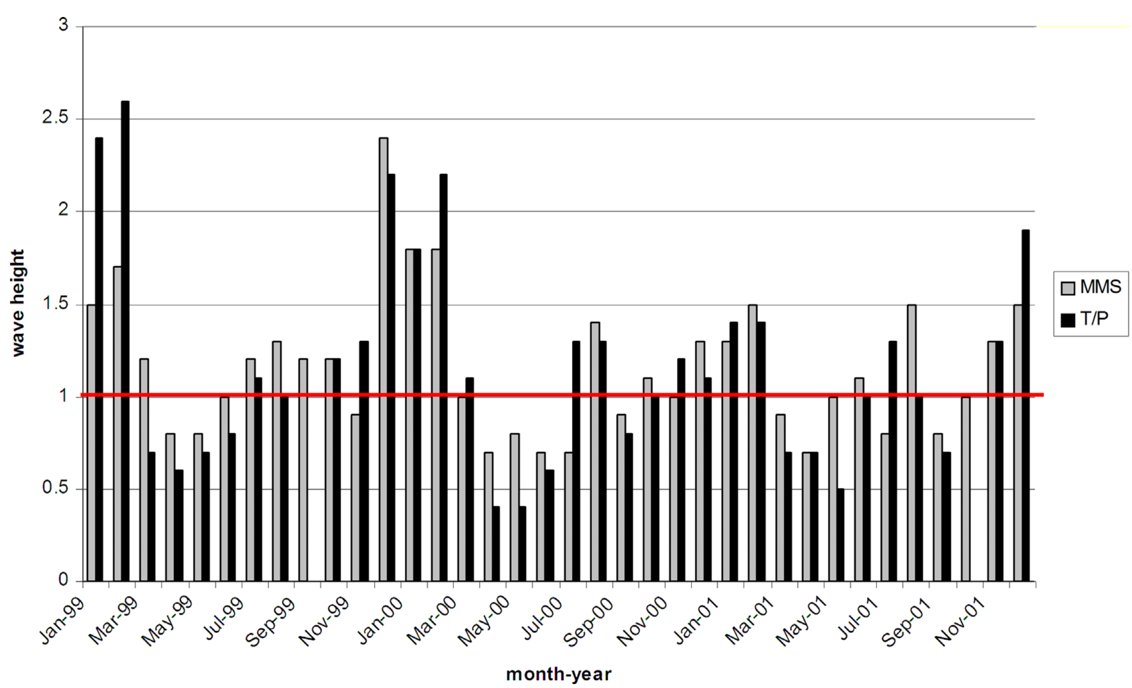


Fig. 6. Ocean Wave Data in Malaysia [20].

Average Tidal Energy Potential Equation [51]

Average Tidal Potential Energy Extractable(Watts) $= AR^2 g/2T$

[where, ρ=Density of water; A=Barrage surface area (m^2); R=Tidal range (m); g=Acceleration due to gravity (m/s^2) and T=Tidal period (s)]

Large amplitude tidal ranges are also associated to strong tidal currents occurrence at ebb and flood tides. Yangon River, on which the main port of Myanmar is situated, is known to have tidal currents of 4–6 knots (2–3 m/s) during spring tides [52].

By analyzing global wave energy data, Myanmar has 5–10 kW/m Annual Mean Exploitable Wave Energy Resource [53] along the

coastline of about 2300 km [25], which would translate to 11.5–23 GW potential.

There are two significant fresh water supplies at the entrance of Gulf of Martaban and Andaman Sea by Irrawaddy River and Than Lwin (Salween) River, two largest rivers in Myanmar, which would be suited for Salinity Gradient Power Production. Irrawaddy River, the largest river in Myanmar has annual discharge rate of 486 km^3/yr (~15,400 m^3/s) while Than Lwin (Salween) River, the second largest river, has annual discharge rate of 211 km^3/yr (~6700 m^3/s) [54]. Based on EU OEA (European Ocean Energy Association) estimated Potential Energy Conversion Rate of 2.6 MW/m^3/s fresh water mixing with seawater, Irrawaddy River yields 35.1 GW and Than Lwin (Salween) River yields 17.42 GW from Salinity Gradient Energy Theoretical Potential [55]. A study by Yale University shows that the highest extractable work in constant PRO (Pressure retarded Osmosis) with a seawater draw solution and river water feed solution is 0.75 kW h/m^3, [56] which would yield 41.58 GW by Irrawaddy River and 18.05 GW by Than Lwin (Salween) River. The salinity content of seawater was reported to be having 34 ppt (g/L) at Bay of Bengal and 33 ppt (g/L) at Andaman Sea [57].

The Bay of Bengal in Myanmar has deep waters more than 1 km range, which is desired for Ocean Thermal Gradient Energy Conversion (OTEC). According to NREL's (National Renewable Energy Laboratory of the United States) Ocean Energy Technology Overview information, temperature difference between sea surface and depth of 1000 m in Myanmar Waters is in the range of 20–22 °C [58].

3.6. Philippines

The potential of ocean energy in the Philippines is estimated at 170,000 MW (150 GW by Mindanao State University then 170 GW update by Philippine Department of Energy) according to a study by the Mindanao State University [59]. In 1988, a study by Uehara, et al. [22] from Japan proposed a design for OTEC power plants in the Philippines. They analyzed ocean temperature profiles, identified potential sites and estimated construction costs. In November 1996, a UNDP-assisted project by OCEANOR visited coastal areas in Batanes Islands, Cagayan, Polilio Islands in Aurora and Bolinao to assess the potential of ocean energy systems such as wave, current, tidal and OTEC in the Philippines [60]. In 1997, the Philippine Government and Blue Energy Engineering Company of Canada came to an agreement to construct a 2200-MW tidal power plant in the San Bernadino Strait. The structure designed to withstand typhoon winds of 150 mph and tsunami waves of 7 m will be a four-kilometer tidal fence consisting of a series of Davis turbines [23,61].

Shown in the Fig. 7 are potential sites for harnessing marine renewable energy (tidal in-stream energy) on the left, wave energy at the center, and OTEC on the right. Researchers from the University of the Philippines (UP) and Nanyang Technological University [27] have estimated the theoretical potential of the Philippines for tidal in-stream energy to be ~200 GW. Of which, ~40–60 GW is practically extractable. Research groups from UP's Marine Science Institute and the College of Engineering has begun to work together on developing ORE in the Philippines starting with proper resource estimates from existing data to identify and prioritize sites for development. Currently, UP has been awarded a research grant from the country's Department of Science and Technology to look into tidal current energy sites in the Philippines with the support of the Department of Energy of the Philippines [27].

3.7. Singapore

A macro-level tidal in-stream energy assessment in Singapore waters has been done by ERI@N (Energy Research Institute at Nanyang Technological University) [63] using data from TMSI (Tropical Marine Science Institute, Singapore). Theoretically, the available Tidal In-Stream Energy (TISE) potential of Singapore is about 3 TW h annually. Technically, the extractable energy with today's TISE harvesting technology (water-to-wire efficiency of around 0.3–0.4) is about 900–1200 GW h/yr. Practically, the limit of extractable energy from Singapore waters without damaging the environment (using a Significant Impact Factor of 10–20%) is about 300–600 GW h per yr; the actual values would be based on detailed resource assessment and sound environmental studies. 600 GWh is ~1.5% of Singapore's electricity demand in 2011. The estimated tidal in-stream energy map of Singapore is shown in Fig. 8. On the other hand, industries like Hann-Ocean, a solution provider for platform and marine renewable energy, has currently launched a containerized modular Drakoo Type-B wave energy converter array (model Drakoo-B0016, 16 kWp) [64].

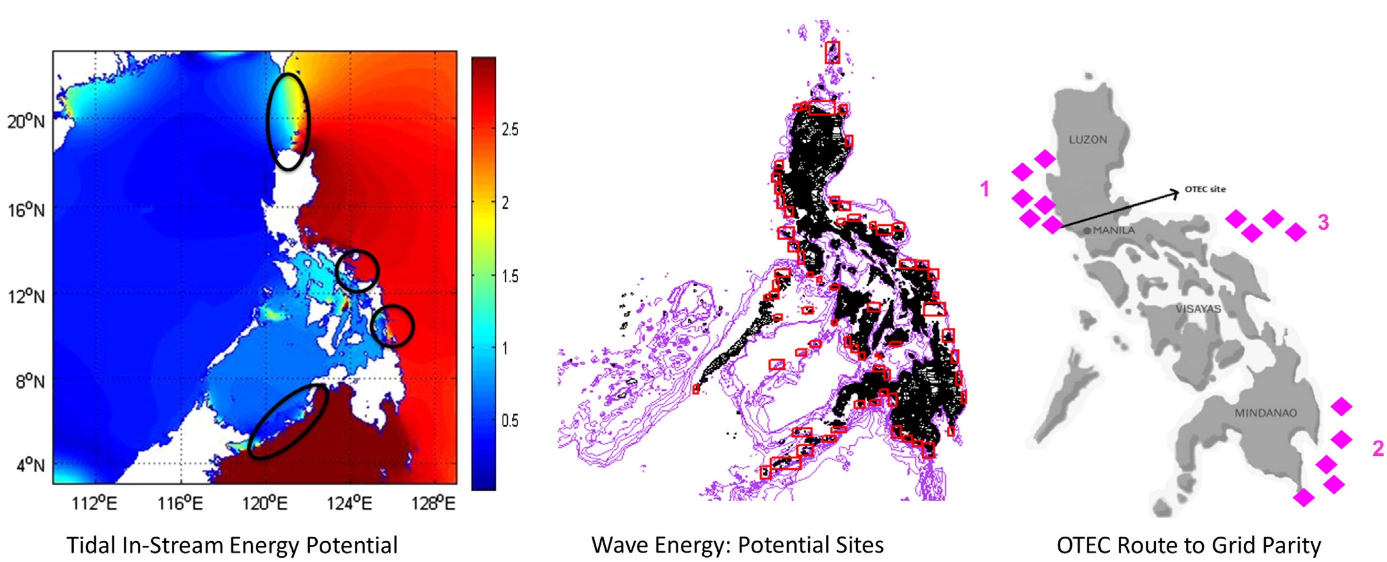
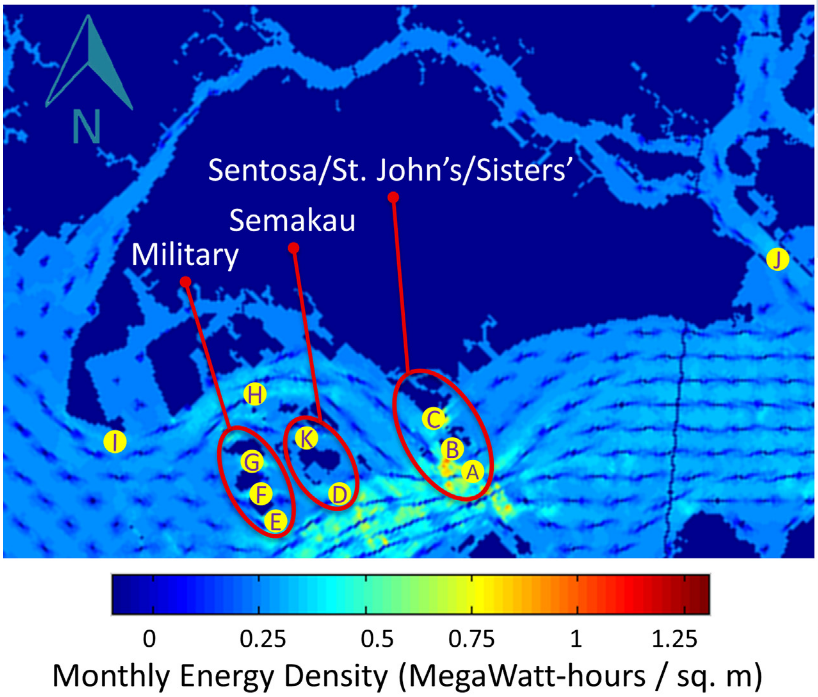


Fig. 7. Potential ocean energy sites in the Philippines [62].

Singapore Tidal In-Stream Energy



Total Resource[1]	~3 TWh/year
Technically[2] Extractable Energy Resource	~900 – 1,200 GWh/yr
Practically[3] Extractable Energy Resource	**~300-600 GWh/yr**

SITE	Peak Power (MW)	Annual Energy Yield (GWh / yr)
A	105	115.96 – 276
B	65	71.78 – 170
C	15	16.57 – 39.4
D	20	22.09 – 52.56
E	3	3.31 – 7.88
F	12	13.25 – 31.53
G	5	5.52 – 13.14
H	15	16.57 – 39.42
I	5	5.52 – 13.14
J	2	2.21 – 5.25
K	3	3.31 - 7.88
TOTAL	**250 MW**	**~300 to 600 GWh/yr**

~0.65% to 1.3%of Singapore's Electricity Demand

Notes:
- [1]Energy Density of ~1MWh/m^2/month
  *5km length (channel width) *50m ave. depth *12 months
- [2]Water-to-Wire Efficiency: 0.3 to 0.4
- [3]Without detrimental environmental effects , Significant Impact Factor (SIF): 0.1 to 0.2
- Velocity Data from PORL, TMSI, NUS

Fig. 8. Singapore Tidal In-Stream Energy [66].

Together with the Technical University of Munich (TUM) CREATE framework for collaboration in Singapore, ERI@N has worked out that a total installed capacity of 250 MW tidal power leads to achievable CO_2 emission reduction of roughly 250 kt/yr (or 1.5%) for electricity production and the calculatory carbon abatement costs are about 75 S$/t.

The Tropical Marine Science Institute [65] of NUS is leading hydrodynamic and wind wave modeling research at the national level. TMSI is building GIS data base of bathymetry and other information important for estimation of tidal, wave, and ocean energy. One theoretical estimate from Nanyang Environment and Water Research Institute (NEWRI) at Nanyang Technological University mentioned the energy potential from the salinity gradient resource between saltwater brine from desalination plants and NEWater non-potable waste water is 100 G Wh/yr.

3.8. Thailand

In Thailand, there have been research activities on studying wave energy, including the installation of an OCEANOR SEAWATCH system on the Gulf of Thailand [15,67]. Although there is a study in 2003 which concluded that there is no potential for ocean-derived renewable energy in the country [68] different research and academic institutes are still in pursuit of studying ocean renewable potential.

The current direction of studies in Thailand is to speed up the identification of the sources and the technology to be applied for tidal energy. Some of the academic institutions in the country have been active in doing research on some potential areas in Thailand. Chulalongkorn University (CU) has set-up the Marine Research Institute on the eastern side of Koh Sichang. It is a group of islands in the inner part of the eastern seaboard of the Gulf of Thailand. CU is open to explore this place in studying ocean renewable energy potential [69].

King Mongkut University of Technology Thonburi (KMUTT) [70] has its own institute, Joint Graduate School of Energy and Environment (JGSEE), which focuses on the energy and environment related studies. They have expertise on coastal ocean modeling. Currently, JGSEE has developed a system of wave data collection installed in the upper Gulf of Thailand. They also pointed Adaman Sea as another potential location for harnessing ORE [71]. The results of their initial studies could be used for further research on pinpointing the suitable ORE technology to be placed on these potential areas.

3.9. Vietnam

As early as in 1996, wave energy and tidal energy have been considered as potential energy sources in the country due to its wave, wind and geography conditions [16,17]. Foreign investors have already shown interest in developing tidal power projects particularly in Binh Thuan Province [16]. There is a total exploitable tidal (barrage) energy of 1753×10^6 kW h/yr and total exploitable capacity of 5514×10^3 kW [94]. For wave energy, Truong

Table 1
Summary of Ocean Renewable Energy data in Southeast Asia[a].

Country	Ocean Renewable Energy Potential/resource data				
	Tidal energy	**Wave**	**OTEC**	**Salinity gradient**	**Other data**
Brunei Darussalam	Tidal Energy: 335 kW (theoretical) 2.08 W/m^2 potential tidal current energy Tidal Barrage: 0.14 to 0.26 W/m^2	0.66 GW (theoretical)	Not possible because the temperature gradient between the top and bottom layers of the ocean is too small (1–6.5 °C) to be utilized.	No Data Available	
Cambodia	tidal range < 1.5 m	No Data Available	No Data Available	No Data Available	
Indonesia	Tidal current: 160 GW (potential in theory); 22.5 GW (technical potential);4.8 GW (in practice) Alas Strait having tidal current energy potential of 641.622 GWh per year (with peak flow: 2 m/s) Extractable: 329.299 GWh per yr	510 GW (potential in theory); 2 GW (technical potential); 1.2 GW (in practice)	57 GW (potential in theory); 52 GW (technical potential); 43 GW (in practice) ΔT at: 600 m–23.18 °C, 800 m–24.73 °C, 1000 m–25.46 °C	No Data Available	potential ocean energy of 10 to 35 MW per kilometer
Lao PDR	Not Applicable	Not Applicable	Not Applicable	Not Applicable	
Malaysia	Tidal Range: 2.7–5.3 m Tidal Current: 14,502 kWh per yr The Straits of Melacca with average 2 m/s (4 knots)	1 m average wave height, 15 kW per meter of wave front 2.6–4.6 kW/m at the northern sections of the east coast of peninsular Malaysia 0.5 to 1.5 kW/m at the southern sections of the east coast of peninsular Malaysia	Sabah: 1200 m depth is found within 125 km distance from the shore and the bottom temperature is about 4 °C at 1200 m water depth	No Data Available	
Myanmar	Tidal Current: Yangon River has tidal currents of 4–6 knots during spring tides Tidal Barrage: 5–7 m Tidal Range Available	11.5–23 GW for 5–10 kW/m from 2300 km shoreline	Western Coast of Myanmar is near to deep waters with depth greater than 1 km	Potential: 35.1–41.58 GW from Irrawaddy River; 17.42–18.05 GW from Than Lwin (Salween) River	
Philippines	Tidal in-stream: 1743 TWh/yr (~200 GW of Power) Theoretical. 350 TWh/yr (~40 GW to 60 GW of Power) Practical. Tidal Barrage: Tidal Range is between 3 m–4 m	Pacific side: 33 kW/m/yr South China Sea side: 35 kW/m/yr	Zambales Energy Island: 10 MW [3] Quezon Wave Farm: 100 KW [3] Pangasinan Energy Island Plant: 50–100 MW Davao Energy Island Plant: 50–100 MW	No Data Available	Total Ocean Energy Resource Potential: 170,000 MW
Singapore	Tidal current: 0–3 m/s; 3 TWh/yr Extractable: 250 MW Peak Tidal barrage: 3 m tidal range	Low waves less than 1 meter (average)	oceanic temperature difference < 20 °C and water depth of Singapore waters is < 1 km	100 GWh/yr	
Thailand	0.001 ktoe	0.50 ktoe	No Potential	No Data Available	
Vietnam	Tidal Energy (Barrage) 1753 GWh/yr (tidal energy)	40–411 kW/m (wave energy flux, offshore)	No Data Available	No Data Available	

[a] This table is a summary of section 3 and the corresponding references can be found in section 3.

Sa (Khanh Hoa), Phu Quy (Binh Thuan), Cu Lao Cham (Quang Nam), Con Co (Quang Tri), and Hon Me (Thanh Hoa) were identified as potential sites [16].

Table 1 shows the authors' generated summary of the collated ocean renewable energy data in the region.

4. Energy policies in Southeast Asia

Although the majority of the Southeast Asian countries are still dependent on traditional sources of energy, each government is striving to tackle the energy “trilemma” as mentioned earlier. Current energy policies in the region try to address the ability to effectively tap and deliver secure and stable energy sources while ensuring economic growth. At the same time and most importantly, energy policies are recently responding to the increasing pressure of achieving environmentally sustainable growth and development.

4.1. Brunei Darussalam

Brunei Darussalam has formulated the Brunei Vision 2035. Although their energy policies are oil- and gas-centric, they formed government-linked organizations like Brunei Energy Association (BENA), Energy Efficiency Conservation Committee (EECC), and Brunei National Energy Research Institute (BNERI) to look into R&D on the RE potential of the country [72]. Ocean energy-related policies have not been developed yet in Brunei.

4.2. Cambodia

There are no specific policies for the development of ocean renewable energy in Cambodia. Mainly, the government policies are targeting the use of renewable energy for the electrification of their rural areas. They came up with policies in the Power Sector Strategy where RE is being pushed to be part of their energy mix. The Rural Electrification Plan is the RE framework of the country; and the Renewable Electricity Action Plan aims to provide cost-effective and reliable electricity through the use of RE technologies [73]. Recently, the Cambodian government created the National Strategic Development Plan Update (2009–2013) which aims that all villages in the country to have electricity by 2020 and by 2030, 70% of the total number of households has access to grid-connected electricity [74]. The Green Growth Roadmap and the National Policy and Strategic Plan for Green Growth 2013–2030 has also been established [74,85].

4.3. Indonesia

Ocean energy was included in Indonesia's energy mix through Act No. 30 of 2007, Amendment of Presidential Decree No. 5 on National Energy Policy 2006 [75]. The government aims to improve the exploration on ocean energy sources, including those from tidal current, waves and ocean thermal. The utilization of ocean energy as alternative source of energy has been further emphasized by the government with the creation of the policy of ocean energy development for electricity in Indonesia (2011). This encourages strategies and legislation improvements to facilitate the development of ocean energy throughout the country [76].

As such, the Indonesian Ocean Energy Association (INOCEAN), or Asosiasi Energi Laut Indonesia (ASELI) in Bahasa Indonesia, was set up to coordinate the efforts in developing ocean energy in Indonesia. INOCEAN has identified suitable sites for tidal, wave and ocean thermal as shown in Fig. 5 [75]. Efforts of creating a roadmap for ORE by INOCEAN have been on-going [77].

4.4. Lao PDR

In Lao PDR, there is no comprehensive plan on the development of renewable energy (or specifically in ocean renewable energy) although the government set the RE share to 30% of the total energy consumption and 10% of the total transport energy consumption from biofuels [78]. The Rural Electrification project Phase 1 (REP 1) was also established to improve the electricity sources for rural areas of the country [79].

4.5. Malaysia

In Malaysia, the target is to achieve 5% of renewable energy contribution for the nation's electricity, which currently stands at about 1% [19]. The Sustainable Energy Development Authority (SEDA) Act 2011 organized the SEDA Authority which has been assigned to lead initiatives in this field. There are also new Feed-In Tariffs (FIT) introduced for renewable energy development [19].

On the Ocean Renewable Energy front, the National Oceanography Directorate (NOD) has also called for national focal point for all oceanographic and marine science activities in Malaysia. It will provide leadership and policies in marine scientific research and development (R&D) undertaken within Malaysian waters as well as facilitate implementation of national and inter-governmental programs pertaining to marine science and oceanographic R&D. Lastly, it will pioneer the drafting of ocean energy technology roadmap [20] for Malaysia [19].

4.6. Myanmar

Myanmar's National Energy Policy is to maintain the status of energy independence of the country, to promote wider use of new and renewable sources of energy, to promote energy efficiency and conservation, and to promote use of alternative fuels in households [80]. The government has developed the Myanmar Agenda 21 which generally aims to facilitate the integration of environment and sustainable development considerations [81]. In January 2013, Myanmar formed the National Energy Management Committee (NEMC) and the Energy Development Committee (EDC) for ensuring the development of all energy and electrical sectors under one umbrella [24,82]. In Myanmar, about 74% of the total population do not have access to electricity [82]. Organizations like Myanmar Engineering Society (MES) and Union of Myanmar Federation of Chambers of Commerce and Industry (UMFCCI) also have activities related to RE and small scale ORE Projects for rural electrification [80,83].

4.7. Philippines

The Philippines has an overarching framework for RE which is the Renewable Energy Act of 2008 [23]. This aims to accelerate the development of the country's RE resources. In relation to this, the Renewable Energy Management Bureau was established to serve as the Department of Energy's lead unit in the implementation of the Act. The National Renewable Energy Board, on the other hand, created sub-committees and working groups to facilitate the formulation of mechanisms, rules and guidelines on RPS (Renewable Portfolio Standard), FIT, Net Metering, Green Energy Option and RE Trust Fund [28].

Philippine Council for Industry and Energy Research and Development (PCIERD) has come up of the ORE Roadmap for the Philippines. The timeline is from 2009 to 2014 and the activities included in the roadmap are: resource assessment (marine current), technology demonstration on marine current, international collaboration research framework and techno-scanning and assessment on ocean energy technologies, wave, tidal and OTEC. This roadmap expects the following outputs in a span of 6 years: marine current demo power plant, marine current resource map and ocean energy technology demonstration project [84].

In 2011, the National Renewable Energy Program (NREP) or the "Green Energy Roadmap 2011" which aims to set-up a policy, program framework and roadmap for RE which targets 15,304 MW installed RE capacity [85].

4.8. Singapore

In 2009, Singapore had pledged to reduce its greenhouse gas emissions (GHG) by 16% below Business-as-Usual (BAU) scenario in 2020 when a global agreement is achieved [86]. Nonetheless, Singapore has embarked on energy efficiency measures, as a key thrust, to reduce emissions from 7% to 11% below 2020 BAU levels [87]. Although at the national level, there has been no policy yet on ORE, universities and energy institutions have continuously been studying the country's potential for ORE specifically on Tidal In-Stream Energy [88,89].

In Singapore, there has been rapid development in terms of marine renewable energy-related activities. Last October 2013, during the Singapore International Energy Week, the Energy Market Authority organized a round table discussion for ORE. Recently, European Marine Energy Centre (EMEC) [90] has signed an international collaboration agreement with the Energy Research Institute at Nanyang Technological University (ERI@N) [90]. Furthermore, a competitive research grant call was announced by the National Research Foundation for the Energy Innovation Research Programme

specifically focused on clean energy generation systems except solar (e.g. wind, marine, etc.) [91].

4.9. Thailand

Thailand has devised the Energy Conservation Promotion Act (ENCON) which aims to establish a 3–5% Renewable Portfolio Standard (RPS) for all new generating capacity installed [92]. Its Alternative Energy Development Plan (AEDP) had categorized tidal wave (together with geothermal energy) under the New Energy Resources. Reports say that the target for energy from wave and tidal current is at 2 MW; but there has been no power generation at present [92,93].

4.10. Vietnam

Vietnam's target for RE share in the total national primary energy consumption is 5% for 2020 and 11% for 2050. In the power sector, the target for RE share is 4.5% by 2030 and 6% by 2050. Although Vietnam is gearing towards the development of biofuels, research institutions and academic organizations still pursue studies on the ORE potential of selected areas in Vietnam.

Table 2 summarizes the ocean renewable energy-related policies in Southeast Asia.

5. Discussion

5.1. ORE resource and technology conditions for SEA

In this section, we analyze the ORE conditions in terms of resource and technologies appropriate for this region and compare these conditions with what has been found out for other regions. Table 3 shows general resource characteristics (temporal variability and predictability) per ORE type with the corresponding ranking for exploitation. Most of the global resources look at the highly-ranked conditions to ensure economic viability of the technology. However, tropical regions such as SEA may have more sites with medium-ranked conditions rather than high-ranking sites.

Southeast Asia, being a tropical region, has 3 main conditions that make it unique in terms of ocean renewable energy: (1) Resource (tides, currents, waves, temperature, and salinity), (2) Marine Environment (e.g. bathymetry and biology), and (3) Marine and Maritime Activity. Each of these conditions is discussed per ocean renewable energy resource below.

In terms of the tidal resource, tides in SEA are relatively lower in magnitude and are dominantly mixed tides with some exceptions in some locations. The SEA region has on the average 2–3 m of tidal difference (except Myanmar having 5-7 m tidal range) which makes tidal barrages not that attractive in terms of economics. Also, tidal barrages have had negative environmental impacts associated with it (since water and sediments – including some nutrients – is somewhat trapped artificially into a 'bay'). Each tidal barrage needs its own environmental impact study. Furthermore, many aquaculture-related activities and marine protected areas are located in the potential sites. These issues may be hindrances to technology adoption and the region might opt to look into other options first before considering tidal barrage-based ocean energy generation.

Because tidal heights are not that high, the currents, therefore, are also not that strong in terms of absolute peaks except for locations that have the oceans (e.g. Pacific Ocean, and Indian Ocean) 'pushing' the water into the seas of countries such as the Philippines and Indonesia. Typical currents, comprising around 60–80% of the region, have an average speed of 1–2 m/s. Technologies being developed in the northern hemisphere (Europe, Canada, and America) are tuned to higher rated speeds. There is a need to tweak the technology to suit tropical conditions including resource characteristics and environmental intricacies. Seabed bathymetries in SEA are not that flat and the slopes are steep even close to shore. Therefore, deployment and installations for SEA waters must consider various appropriate/suitable methods and technologies for these conditions. The industry also has to keep in mind other stakeholders who are users of the marine space such as fishermen, leisure groups, and transport. In SEA, the maritime industry in a lot of the rural areas is not that well-regulated thus posing some possible security risks.

Good wave resource ($Hs > 1$ m) are primarily found in areas with exposure to the seas and oceans (e.g. The Philippines, Indonesia, Malaysia, Vietnam, Thailand, Myanmar). Wave Energy conversion devices have also been developed in the region. Of notable merit are the prototypes that were developed deployed in Malaysia and Indonesia by respective local groups. Wave Energy extraction makes sense for locations that have been known as surfing sites in SEA. The development possibilities, however, must be taken with a grain of salt, since some of these wave energy locations are also affected by typhoons and storms.

Ocean Thermal Energy Conversion (OTEC) resource (i.e. temperature difference of at least 20 °C) is available almost all over the SEA region except in locations where the waters are too shallow (i.e. Depth < 200 m, e.g. Singapore). OTEC is thus one of the more lower-hanging fruits in terms of resource. The issue with OTEC in SEA is that the locations may be prone to typhoons and storms, so bulk of the power plant needs to be located on shore, which then thus entails longer intake pipes to get the cold water from below the sea. There is some talk of ship-based OTEC or OTEC barges that would produce hydrogen and store them for transport instead of having electricity brought to shore. Many projects are at exploratory stage now. Perhaps only 2 projects are worth mentioning: (1) Philippines OTEC Pilot Plant (10 MW) by Energy Island Bell Pirie Ltd. (UK) and (2) OTEC Study in Sabah by Ocean Thermal Energy Corporation (USA) which had the blessing of the Prime Minister of Malaysia in 2012.

Salinity is typically between 31 and 34 psu and with the abundance of fresh water tributaries to the sea or river-to-sea estuaries. Salinity Gradient Power may have a lot of options in terms of locations in SEA but the technology is still in the development and demonstration stages in terms of readiness. When Salinity gradient-based power does mature, there are also issues that have to do with the local environment (especially if salinity levels have some form of environmental impact associated with it).

In summary, comparing the conditions in Southeast Asia and the global playing field, SEA should be treated as a region with great potential for ocean renewable energy development but harnessing the resource will entail some technology adaptation steps to suit the tropical waters of the region.

5.2. Comparison of ORE policies between SEA and the rest of the world

On the policy side, different tools are used by governments to increase the uptake of ocean renewable energy in their own country. Most of the ORE policies are placed under the umbrella of a general renewable energy policy framework, however even with the presence of an RE policy, this does not guarantee that ORE development is expected. There are certain specific policy tools that a country could consider in encouraging the push for ocean renewables.

Fig. 9 shows the development indicators of ORE per region. The three main policy sectors that need to be focused on for the advancement of ORE development are: (1) regulatory policies and existence of targets, (2) fiscal incentives and (3) public financing [96]. All the regions have at least an established roadmap of RE

Table 2
Summary of Renewable/Ocean renewable energy-related Policies in SEA region[a].

Country	National plan/government strategy plan for RE/ORE	Brief description
Brunei Darussalam	Brunei Vision 2035 (Report on Brunei Darussalam)	Economy's major goal for the next three decades is economic diversification, along with strengthening of the oil and gas sector.
	Government recognizes the fact there is need for preservation, conservation and efficient use of energy	Formation of Brunei Energy Association (BEna) and Energy Efficiency Conservation Committee (EECC) (Report on Brunei Darussalam)
Cambodia	Power Sector Strategy (1999–2016)	Electric Strategy, Renewable Energy, Power Sector, and Wood Energy Strategy
	Rural Electrification Action Plan by Renewable Energy Policy	Enabling framework for renewable energy technologies to increase access to electricity in rural areas.
	Renewable Electricity Action Plan 2002–20122002–2012 (REAP)	Aims to provide cost-effective and reliable electrification of rural communities through renewable energy technologies
	National Strategic Development Plan Update 2009–2013	Aims that by 2020, all villages in the country have access to electricity and by 2030, 70 percent of the total households has access to grid electricity Green Growth Roadmap and the National Policy and Strategic Plan for Green Growth 2013–2030
Indonesia	Presidential Decree in 2006	
	Act No. 30 of 2007, Amendment of Presidential Decree No.5 on National Energy Policy 2006	Ocean energy was included into the mix in 2007; aims to improve the ability on research and development in the field of ocean energy to be economically utilized Supports the enhancement of national capacity to increase the energy utilization of currents, waves and ocean water temperature differences, both industrial and domestic scale throughout Indonesia potential marine areas.
	Indonesian Ocean Energy Association (INOCEAN), or Asosiasi Energi Laut Indonesia (ASELI)	To co-ordinate the efforts in developing ocean energy in Indonesia
Lao PDR	No comprehensive RE Policy	30% RE Share of total energy consumption; 10% of the total transport energy consumption from biofuels (Renewable Energy Development Strategy in Lao PDR)
	Renewable Energy Development Strategy	Aims to increase share of RE by 30% of the total energy consumption
	Rural electrification project phase 1 (REP I)	Improved the electricity from 16% in 1995 to 63% in 2009, provide grid connected and off-grid electricity for 40,000 rural household during 4 years
Malaysia	New RE Policy	Targeted 5% (2011) RE contribution for electricity, achieved about 1% Legislation, enforcement and incentive were approved in 2011.
	Sustainable Energy Development Authority (SEDA) Act 2011	An Act to provide for the establishment of the Sustainable Energy Development Authority (SEDA) of Malaysia and to provide for its functions and powers and for related matters.
	Renewable Energy Act 2011	To provide for the establishment and implementation of a special tariff system to catalyze the generation of renewable energy and to provide for related matters.
	National Oceanography Directorate (NOD)	National focal point for all oceanographic and marine science activities Provides leadership and policies in marine scientific research and development (R&D) undertaken within Malaysian waters Facilitate implementation of national and intergovernmental program pertaining to marine science and oceanographic R&D Draft ocean energy technology roadmap
Myanmar	National Energy Policy of Myanmar	To maintain the status of energy independence of the country, to promote wider use of new and renewable sources of energy, to promote energy efficiency and conservation, and to promote use of alternative fuels in household
	Myanmar Agenda 21	General aim of facilitating the integration of environmental and sustainable development consideration
	National Energy Management Committee (NEMC)	With objective of integrating diversified energy and related fields under one umbrella
Philippines	Renewable Energy Act of 2008	Aims to accelerate the development of the country's renewable energy resources by providing fiscal and non-fiscal incentives to private sector investors and equipment manufacturers/fabricators/suppliers
	Renewable Energy Management Bureau	Department of Energy's lead unit in the implementation of the Acts
	National Renewable Energy Board	Created sub-committees and working groups to facilitate the formulation of mechanisms, rules and guidelines on RPS, FIT, Net Metering, Green Energy Option and RE Trust Fund
	National Renewable Energy Program (NREP) or the "Green Energy Roadmap 2011"	Sets up a policy, program framework and roadmap for RE which targets 15,304 MW installed RE capacity
Singapore	Clean Energy Program Office (CEPO), Clean Energy Research Program (CERP), Experimental Power Grid Center (EPGC), Market Development Fund (MDF) and Clean Energy Research and Testbedding Program (CERT)	The Government at the national level also has initiated the development of REs by building energy R&D infrastructure and test-bedding platforms, establishing energy R&D programmes and putting strategic energy R&D funding in place
	Energy Efficiency Program Office (E2PO)	Promotes energy efficiency in the various sectors through the Energy Efficient Singapore (E2 Singapore) policies and measures.
	Sustainable Development Blueprint	Sets a target to reduce energy intensity (per dollar GDP) by 20% from 2005 levels by 2020, and by 35% from 2005 levels by 2030
Thailand	ENCON (Energy Conservation Promotion Act)	Aims to establish a 3–5% Renewable Portfolio Standard (RPS) for all new generating capacity installed, and the targeted share for renewable power generation has been proposed at 6% of total generating capacity by 2011

Table 2 (*continued*)

Country	National plan/government strategy plan for RE/ORE	Brief description
	Small Power Produces (SPP) and Very Small Power Producer	Launched to support renewable electricity production from biogas, biomass, municipal solid waste (MSW), wind, solar, and other renewable energy sources.
	Alternative Energy Development Plan (AEDP)	Categorized tidal wave under the New Energy resources (together with geothermal).
Vietnam	Vietnam Master Plan no. 6 for national energy development	Share of RE in the total national primary energy consumption: 5% (2020), 11% (2050) Establishment of RE development fund
	Development of biofuels in Vietnam with a vision to 2015	Ethanol and vegetable oil production: 250 thousand tons (2015), 1.8 mili. tons (2025)
	Vietnam Master Plan no. 7 for national energy development	Share of RE in power sector: 4.5% (2030), 6% (2050) By 2020, 600 thousand households will be supplied with electricity from RE.

[a] This table is a summary of section 4 and the corresponding references can be found in section 4.

Table 3
[a] ORE Resource and Technology Categories and criteria applied by Hammar et al. [95].

	Wave power	Ocean Thermal Energy Conversion (OTEC)	Tidal barrages	Tidal In-Stream Energy (tidal current turbines)
Temporal variability	Daily and seasonal	Seasonal	Hourly and weekly	Hourly and weekly
Predictability	Moderate	High	High	High
Ranking				
High	≥ 25 kW m^{-1}	$\geq 20\Delta T$, ≤ 5 km	≥ 5 m mean tidal range	≥ 2 m s^{-1} peak speed
Medium	15–25 kW m^{-1}	$\geq 20\Delta T$, ≤ 10 km	2.4–5 m mean tidal range	≥ 1.5 m s^{-1} peak speed

[a] Temporal variability, predictability, and ranking criteria refer to annual means if not specified otherwise.

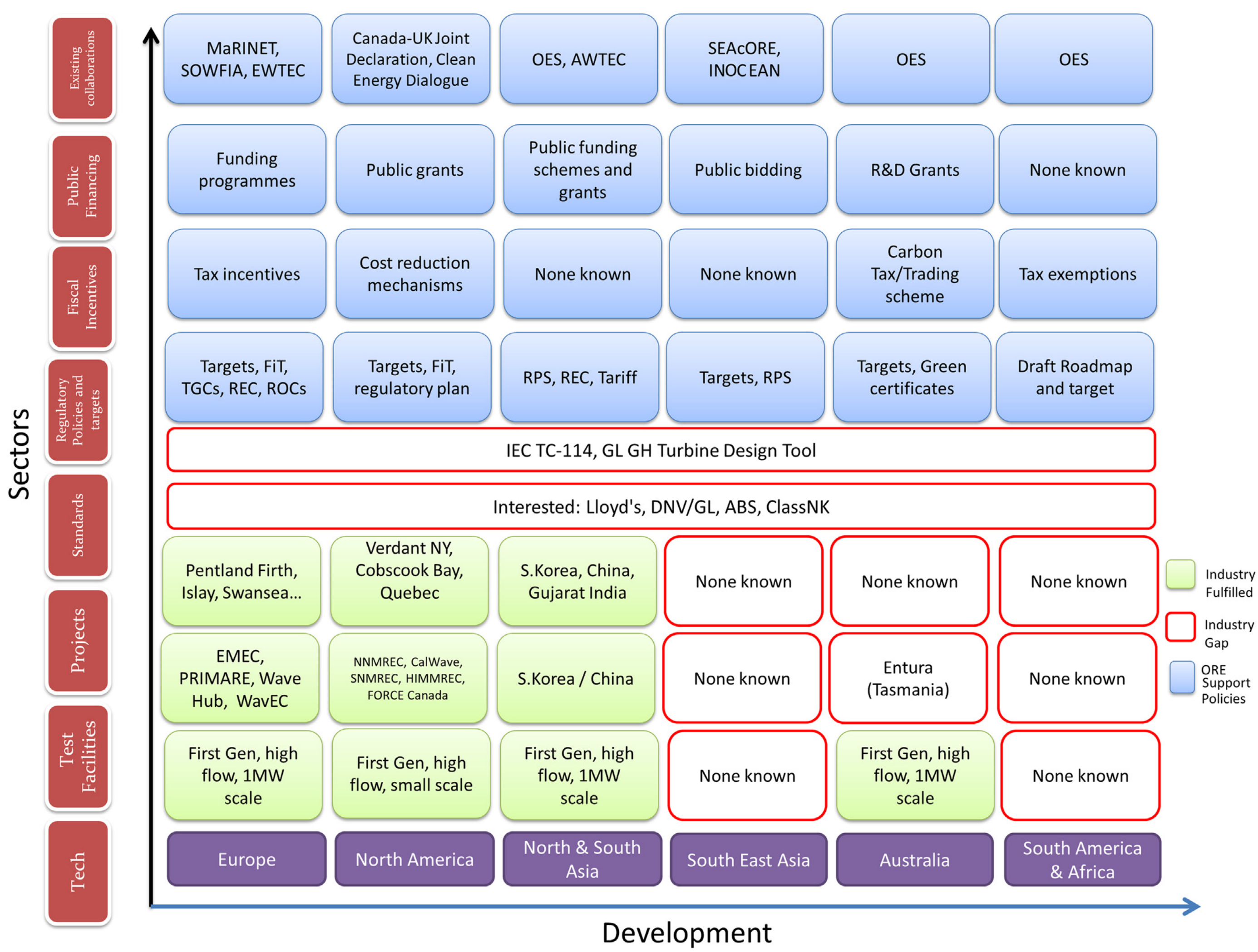


Fig. 9. Development indicators of ORE per region [8,96,97].

which includes specific targets for ocean renewables. For example, countries like Ireland has a Refit tariff of €220 MW for wave and tidal. Belgium, on the other hand, implements Tradable Green Certificates to support RE production. Every RE technology being proposed will be analyzed by a stakeholder to know the level of support to be given. There are also fiscal incentives available for countries to be utilized. In the United States, they have cost-reduction schemes like the marine and hydrokinetic (MHK) cost reduction goal of 12–15 cents per kW h by 2030. In North and South Asia and Australia, they make use of public financing tools in securing funding for the development of ORE technologies. South Korea government agencies like Ministry of Oceans and Fisheries and Ministry of Trade, Industry and Energy lead the public funding for ORE RD&D program (e.g. support mainly on demonstration projects) [97].

Although most of the countries in Southeast Asia are already engaged in ocean renewable energy R&D, there is still a challenge of resource assessment in the region. Indonesia, Malaysia and Singapore are relatively developed in terms of their R&D on ORE while Brunei has yet to start exploring ORE as a possible alternative renewable energy other than wind. For the others, the lack of resource assessment is because of the lack of access to right information and expertise in studying ocean renewable energy (e.g. financial resources to support local R&D). Thailand could have the expertise on ocean energy modeling but the technology demonstrations of ORE converter designs and models are still required to be developed and tested. For some countries, ocean renewable energy is not a priority due to the lack of available data for further studies.

On the national level, the dilemma lies on the enabling policies for ocean renewable energy, and for other renewable energy sources as well. Different countries in the region vary in the level of "policy push" for ocean renewable energy or even for renewable energy in general. Lao PDR, Cambodia and Brunei Darussalam are among the Southeast Asian countries which have no comprehensive plan on renewable energy; however, their national governments have created other policies that enable the usage of renewable energy in their country. Vietnam, Thailand, Myanmar, Singapore and Philippines all have the enabling national policy framework for renewable energy but policies specifically catering to ocean renewables have yet to be developed. Among the Southeast Asian countries, Indonesia, Philippines and Malaysia have the most concrete policies on ocean renewable energy development.

Although it can be said that there are available data to study the potential of ocean energy, the further development of ocean renewables from R&D to commercialization is still a work-in-progress. Some Southeast Asian countries already have concrete plans and policies for ocean renewables. Some are on their R&D stage and/or still pushing for inclusion of ocean renewables in their renewable energy national plan. For few, they are still on the nascent stage of studying the data from their ocean. Table 4 is a summary of the level of each Southeast Asian country in terms of R&D, resource assessment, technology, policy existence and existence of ocean renewable energy roadmap. These are based from the collated data (i.e. summary tables of the ocean renewable energy potential and the ORE-related policies above). These collated data are not exhaustive.

Table 4 categorizes each country into four stages of development

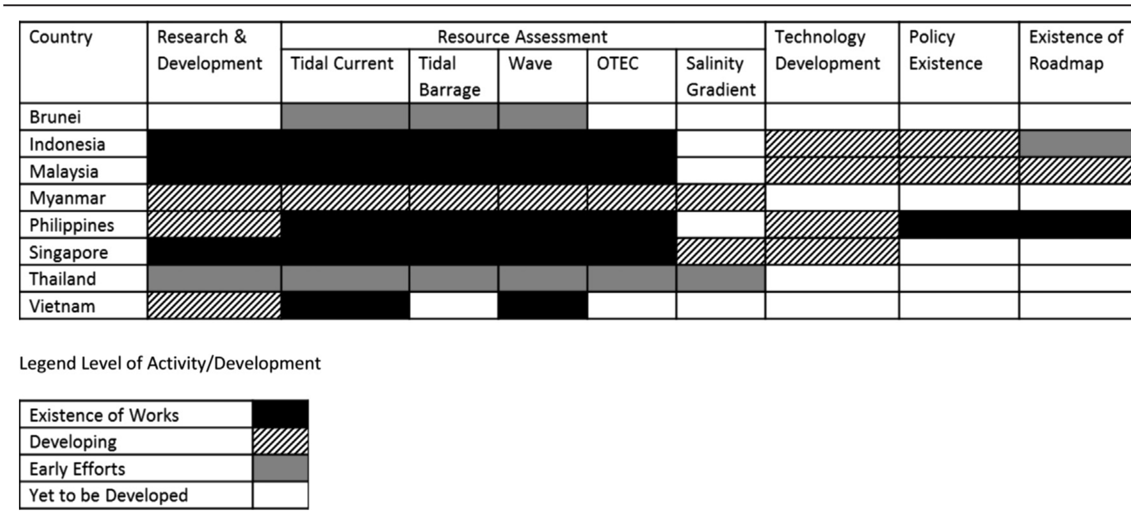
1) Existence of works
2) Developing
3) Early Efforts
4) Yet to be Developed

For example, the resource assessment has been divided into different types of ocean renewable energy (tidal current, tidal barrage, wave, OTEC and salinity gradient). In this area, Malaysia is relatively developed in terms of resource assessment. Malaysian studies on ORE have already included potential locations for tidal current, barrage, wave and OTEC. Indonesian ORE studies are also similar – INOCEAN has already identified location maps of ORE in Indonesia. Some countries like Philippines and Singapore have nascent development in terms of resource assessment of ORE. ORE studies in these countries have already given estimated energy that could be generated from ocean.

In technology development, most of the SEA countries are on its developing stage. Most of the countries are on its prototyping stage and deployment in smaller scale. In terms of policies and roadmaps, governments in SEA have yet to see ORE as alternative source of energy; with the exception of Philippines which already has an existing ORE Roadmap.

As a region, the International Energy Agency indicated that there are both economic and non-economic barriers in deploying renewable energy in Southeast Asia in general. Although it has improved in recent years, the environment for investment and

Table 4
Development matrix of Ocean Renewable Energy in Southeast Asia.



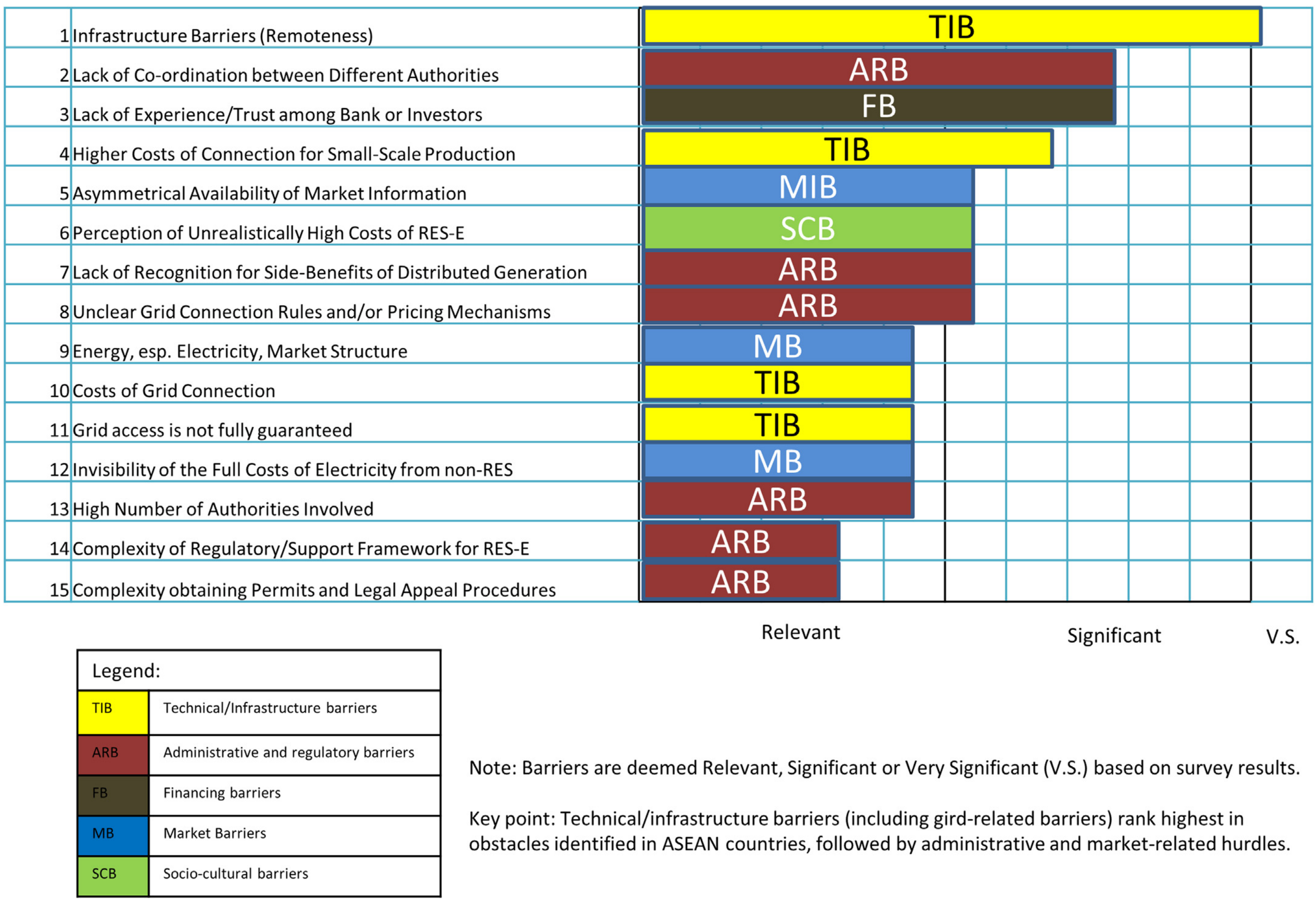


Fig. 10. Non-economic barriers in selected ASEAN countries in deploying renewable energy in the region [13].

financing for renewables in ASEAN-6 (Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam) "still fall short of those required to achieve a low-carbon energy revolution" [13]. This situation is said to be partly caused by non-economic challenges that the region has to face. Few of these are infrastructure and grid-related problems and regulatory and administrative hurdles. According to a survey discussed in the IEA study, the following are the perceived risks that potential investors have in the region: legal security, negative policy changes affecting renewables, main financial support, and total revenues received [13].

There are measures that could help eliminate these existing non-economic barriers but as the IEA recommended, they mostly require coordination among all major stakeholders. The key to encourage well-targeted investment not only in ocean renewable energy but in renewable energy in general, is to "implement effective and coherent renewable energy policies with a long-term strategic perspective." [13]

Fig. 10 shows the IEA table on the ranking of non-economic barriers in selected ASEAN countries in deploying renewable energy in the region.

5.3. *The ASEAN energy cooperation*

The ASEAN continuously tries to foster energy cooperation among its member countries as a means of facing the barriers and challenges in providing energy security in the region. Efforts have been made in promoting energy conservation and encouraging the use of renewable energy in the region.

Some of the plans that they have discussed are the following: the inter-connection of ASEAN electricity grid; and the creation of HAPUA (Heads of ASEAN Power Utilities/Authorities) in 1981 to formulate the ASEAN Power Grid. These take into account the Trans ASEAN Gas Pipeline (TAGP) Plan and other resources (hydro in particular) within the region. Other projects involve ASEAN Vision 2020, ASEAN Five-Year Plans which also highlights the Renewable Energy Utilization among the countries in the region [9,98,99].

Despite several initiatives to start cooperation projects, the road to developing these "has been quite slow, due to financial constraints, technical difficulties, differences in the industry regulatory frameworks among ASEAN countries, and some other factors." As in any international relations, "energy cooperation within ASEAN is challenged by its individual member's energy priorities, bilateral trade partners and development dynamics beyond the borders" [98].

Furthermore, not only economic factors are seen to be barriers to strengthen the cooperation in the region. Political factors such as "faster development of other regions (including neighbors, Northern Asia and India), cross border disputes, and internal rivalry are also things to be considered when assessing whether ASEAN countries would maintain its goal for energy cooperation [98].

However, for countries in Southeast Asia to deploy and develop ocean renewable energy, they must first address a number of issues, namely, (1) the lack of information about ocean renewable energy potential, (2) the lack of local expertise and capacity building, (3) the need to develop local technologies, and (4) the

absence of policies to support the deployment and development of ocean renewable energy.

In summary, the uptake of ocean renewable energy in Southeast Asia is a reachable goal. Taken with a grain of salt, there are technical, political and both economic and non-economic barriers that still hinder its development in the region.

6. Conclusions and recommendations

This paper discusses the need of the region to continuously search for alternative source of energy instead of relying on oil and gas. Specifically, this study looks at the current status of ocean renewable energy in the Southeast Asian region as potential source of renewable energy. It proves that there is a potential for ocean renewable energy in the region based from the primary and secondary data gathered for this research. The collated data are useful in preliminary resource assessment of the region.

The potential, however, varies from one country to another. The difference in potential can be attributed to how much information is available or has been gathered. For instance, countries like Indonesia, Malaysia, the Philippines, and Singapore have gone as far as deploying wave energy devices in their waters. In countries like Thailand, Vietnam, Brunei, and Myanmar, there are available tidal current, tidal barrage, wave, and ocean thermal energy conversion (OTEC) data but actual prototyping and deployment have yet to be done.

While R&D for ocean renewables is present in the region, there is a need to address the huge challenge of resource assessment. Conducting resource assessment is crucial for countries in Southeast Asia to fully harness and utilize their ocean renewable energy potential.

As a whole, the region remains low in achieving its targets for a low-carbon future. An International Energy Association (IEA) study in 2007 [13] has shown that in Southeast Asia, both economic and noneconomic barriers play a role in discouraging foreign investments in renewable energy. Infrastructure, which encompasses policies, legal security, and coordination among government stakeholders with regard to investments, among others, has been identified as a major barrier. Potential investors consider a weak infrastructure as a risk and thus, countries with weak infrastructures are less likely to attract foreign investments [13].

Thus, existing economic and noneconomic barriers should be taken into account in order to optimize and maximize the full potential of ocean renewable energy in the region. Coordination among all major stakeholders (e.g., academic institutions, industry players, policymakers) and implementation of effective and coherent renewable energy policies with a long-term strategic perspective are the first key steps in addressing the barriers.

Ocean renewable energy experts from different academic and research institutions are continuously studying the potential of ORE by conducting research, workshops and seminars locally and across the region. Perhaps these studies and activities could be made larger on a regional scale by providing a platform for exchange of status, plans, ideas, initiatives, and experiences among different ocean renewable energy-related stakeholders (academic institutions, industry players and most especially policy-makers) to set, assist, augment, or facilitate standards for ocean renewable energy in the Southeast Asian region. It is in this spirit that the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE) was formed. SEAcORE's mission, basically, is to increase the uptake of ocean renewables in Southeast Asia. This platform would also be a means of addressing the challenges (e.g. coordination problem across levels of R&D, policy-making, and implementation to commercial scale) that ocean renewable energy in the Southeast Asian region faces.

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References

[1] Marine Renewable Energy (Wave and Tidal) Opportunity Review, [Online]. Available: 〈http://www.oceanrenewable.com/wp-content/uploads/2007/03/orereport.pdf〉, [accessed 8.05.13].
[2] Soerensen HC, Weinstein A. Ocean Energy: Position paper for IPCC, January 2008. [Online]. Available: 〈http://123seminarsonly.com/Seminar-Reports/037/44753036-Ocean-Energy-IPCC-Final.pdf〉, [accessed 1.07.14].
[3] IEA-OES, Ocean Energy: Global Technology Development Status, March 2009. [Online]. Available: 〈http://www.energybc.ca/cache/tidal/annex_1_doc_t0104-1.pdf〉, [accessed 1.07.14].
[4] Bahaj A. Generating electricty from the oceans. Renew Sustain Energy Rev 2011;15(7):3399–426.
[5] Ocean Energy Systems, Ocean Energy Systems, [Online]. Available: 〈http://www.ocean-energy-systems.org/ocean_energy/〉, [accessed 20.07.13].
[6] Ocean Energy, Low Carbon Green Growth Roadmap for Asia and the Pacific, [Online]. Available: 〈http://www.unescap.org/esd/environment/lcgg/documents/roadmap/case_study_fact_sheets/Fact%20Sheets/FS-Ocean-energy.pdf〉, [accessed 20.07.13].
[7] Harnessing Energy from the Oceans, Environment News Network, [Online]. Available: 〈http://aceer.uprm.edu/pdfs/harnessing_energy_oceans.pdf〉, [accessed 17.07.13].
[8] Annual Report 2012 Implementing Agreement on Ocean Energy Systems, Ocean Energy Systems (OES), [Online]. Available: 〈http://www.ies.org/media/openbulletin/OES2012.pdf〉.
[9] Memorandum of Understanding on the ASEAN Power Grid, Association of Southeast Asian Nations (ASEAN), [Online]. Available: 〈http://www.asean.org/communities/asean-economic-community/item/memorandum-of-understanding-on-the-asean-power-grid〉, [accessed 19.06.13].
[10] Lewis A, Estefen S et al. Ocean Energy, 2011. [Online]. Available: 〈http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch06.pdf〉, [accessed July 2014].
[11] Si OCEAN, "Ocean Energy: Cost of Energy and Cost Reduction Opportunities," May 2013. [Online]. Available: 〈http://si-ocean.eu/en/upload/docs/WP3/CoE%20report%203_2%20final.pdf〉. [accessed 1.07.14].
[12] Mueller M, Wallace R. Enabling science and technology for marine renewable energy. Energy Policy 2008;36(12):4376–82.
[13] Deploying Renewables in Southeast Asia, International Energy Agency, [Online]. Available: 〈http://www.iea.org/publications/freepublications/publication/Renew_SEAsia.pdf〉, [accessed 8.05.13].
[14] Cavallaro G, Abundo M. Southeast Asian collaboration for ocean renewable Energy: a proposal. Singapore: Energy Research Institute at Nanyang Technological University (ERIAN); 2012.
[15] Yupapin P, Chitsakul P, Pipatsart S. A computational study of water waves for alternative energy use. In: Proceedings of international conference on green and sustainable innovation, Changmai; 2006.

[16] Bridge V, Binh Thuan on tidal energy development, 1 July 2011. [Online]. Available: ⟨http://english.vietnamnet.vn/en/environment/10128/binh-thuan-keen-on-tidal-energy-development.html⟩, [accessed 18.06.13].
[17] Van N. A study of the potential of renewable energy source and its application in Vietnam. Renew Energy 1996;1–4(9).
[18] Malik A. Assessment of the potential of renewables for Brunei Darussalam. Renew Sustain Energy Rev 2011;1(15):427–37.
[19] Yaakob O, Rashid T Ab, Mukti M. Propects for Ocean Energy in Malaysia. In: Proceedings of international conference on energy and environment, Universiti Teknologi Malaysia, Johor Bahru; 2006.
[20] Yaakob O. Marine renewable energy initiatives in Malaysia. Singapore: Southeast Asian Collaboration for Ocean Renewable Energy; 2013.
[21] Lim Y, Koh S. Analytical assessments on the potential of harnessing tidal currents for electricity generation in Malaysia. Renew Energy 2010;5(35):1024–32.
[22] Uehara H, Dilao C, Nakaoka T. Conceptual design of ocean thermal energy conversion (OTEC) power plants in the Philippines. Sol Energy 1988;5(41):431–41.
[23] Philippines Tidal Power, Fujita Research, [Online]. Available: ⟨http://www.fujitaresearch.com/reports/tidalpower.html⟩. [accessed 18.06.13].
[24] M. President Office, Notification No. (12/2013) The New Light of Myanmar, 10 January 2013. [Online]. Available: ⟨http://www.burmalibrary.org/docs14/NLM2013-01-10.pdf⟩. [accessed 19.06.13].
[25] Kyaw LS. Burma (Myanmar). Encyclopedia of the World's Coastal Landforms. Netherlands: Springer; 2012; 1081–6.
[26] Study and Assessment the Potential of Ocean Energy in Vietnam and Proposing Some Solution to Use National Project on Marine Technologies, Ministry of Science and Technology, Ho Chi Minh; 2010.
[27] Buhali M, Ang MR, Paringit E, Villanoy C and Abundo M, Tidal In-Stream Energy Potential of the Philippines: Initial Estimates. In: Proceedings of the 1st Asian Wave and Tidal Conference, Jeju Island; 2012.
[28] Guzman RDe, The Renewable Energy Act of 2008 Implementation 2012, [Online]. Available: ⟨http://eeas.europa.eu/delegations/philippines/documents/press_corner/renewable_energy_act2008_deguzman_en.pdf⟩, [accessed 19.06.13].
[29] Low M, Creating a balanced energy mix in Southeast Asia Energy Studies Institute at NUS, 12 June 2012. [Online]. Available: ⟨http://esi.nus.edu.sg/publications/2012/06/14/creating-a-balanced-energy-mix-in-southeast-asia⟩. [accessed 5.09.13].
[30] Brunei Darussalam, Fao Corporate Document Repository, [Online]. Available: ⟨http://www.fao.org/docrep/003/x6900e/x6900e08.htm⟩. [accessed 21.07.13].
[31] Energising Our Nation, Singapore Statistcs 2012, Energy Market Authority, [Online]. Available: ⟨https://energypedia.info/index.php/Cambodia_Country_Situation#Energy_Access.5B5.5D⟩. [accessed 3.06.13].
[32] Summary – Primary Energy Supply, Suruhanjaya Tenaga, 2011. [Online]. Available: ⟨http://meih.st.gov.my⟩. [accessed 21.07.13].
[33] Cambodia Country Situation, [Online]. Available: ⟨https://energypedia.info/index.php/Cambodia_Country_Situation#Other_RE_sources⟩. [accessed 3.06.13].
[34] Indonesia's Energy Security and Geothermal Development, [Online]. Available: ⟨https://www.indonesiasoken.com/pdf/FREE_046_20120730_energy%20report.pdf⟩. [accessed 18.06.13].
[35] Philippine Country Report, From Idea to Action: Clean Energy Solutions for Asia to Adress Climate Change, USAID, 2007. [Online]. Available: ⟨https://www.indonesiasoken.com/pdf/FREE_046_20120730_energy%20report.pdf⟩. [accessed 18.06.13].
[36] Thailand Country Report, [Online]. Available: ⟨http://www.eia.gov/countries/cab.cfm?fips=TH⟩. [accessed 3.06.13].
[37] Laos: The Hydroelectric Battery of Southeast Asia, [Online]. Available: ⟨http://esi.nus.edu.sg/publications/2013/01/24/laos-the-hydroelectric-battery-of-southeast-asia⟩. [accessed 5.09.13].
[38] Myanmar Energy Sector Initial Assessment, Asian Development Bank, 2012. [Online]. Available: ⟨http://www.adb.org/sites/default/files/myanmar-energy-sector-assessment.pdf⟩. [accessed 13.05.13].
[39] Energy Information Administration, Country Benefit Analysis: Vietnam," [Online]. Available: ⟨http://www.eia.gov/cabs/Vietnam/Full.html⟩. [accessed 3.06.13].
[40] Renewable Energy for Southeast Asia: A Market Ready for Takeoff, Knowledge at Wharton, [Online]. Available: ⟨http://knowledge.wharton.upenn.edu/article.cfm?articleid=3086. [accessed 21.07.13].
[41] Abbugao M, Renewable Energy in Southeast Asia, AFP, 22 February 2011. [Online]. Available: ⟨http://www.google.com/hostednews/afp/article/ALeqM5gMEPexBrKKotpyJIlXI3lFTnFGNw?docId=CNG.a9752ab9a9ad29f39dac145a6ef0e9bf.301⟩. [accessed 21.07.13].
[42] Abubakar H, The Occassion of 1st International Conference of the Institution of Engineering and Technology, Brunei Darussalam Network, Energy Department, [Online]. Available: ⟨http://www.energy.gov.bn⟩. [accessed 3.05.13].
[43] Ocean Energy Potential, Indonesian Ocean Energy Association (INOCEAN), Jakarta; 2012.
[44] Aziz NS, Tidal energy resources assessment in Indonesia: a case study in Alas Strait, July 2009. [Online]. Available: ⟨http://repository.tudelft.nl/assets/uuid:1ceaf756-766f-41e6-8746-315caee62518/Aziz.pdf⟩. [accessed 5.09.13].
[45] Blunden L, Bahaj A, Aziz N. Tidal current power for Indonesia? An initial resource estimation for the Alas Strait Renew Energy 2013;49:137–42.
[46] U.S. Department of Commerce, Renewable Energy Market Assessment Report: Indonesia, [Online]. Available: ⟨http://trade.gov/td/energy/Indonesia%20Renewable%20Energy%20Assessment%20(FINAL).pdf⟩.
[47] Ali M, Tangang F, Liew J. Wave energy potential along the east coast of Peninsular Malaysia. Energy 2014;68:722–34.
[48] Lim S, Koh S. Meeting energy demand in a developing economy without damaging the environment - a case study in Sabah, Malaysia. Energy Policy 2010;8(38):4719–28.
[49] Chong H-Y, Lam W-H. Ocean renewable energy in Malaysia: The potential of the Straits of Malacca. Renew Sustain Energy Rev 2013;23:169–78.
[50] Admiralty Total Tide, United Kingdom Hydrographic Office, United Kingdom; 2011.
[51] Boyle GE. Renewable energy: power for a sustainable future. 2nd ed. Oxford, UK: Oxford University Press; 2004.
[52] Port of Yangon, Ministry of Transport, 2013. [Online]. Available: ⟨http://www.mot.gov.mm/mpa/ygn_ports.html. [accessed 16.04.13].
[53] Reguero BE. Evaluation of global wave energy resource. Spain: OCEANS 2011, IEEE; 2011.
[54] Gaillardet J, Dupre B, Allegre C. Global sillicate weathering and CO_2 consumption rates deduced from the chemistry of large rivers,. Chem Geol 1999;1–4(159):3–30.
[55] Technology: Salinity Gradient, EU-OEA, [Online]. Available: ⟨http://www.oceanenergy-europe.eu/index.php/ocean-energy/technology/13-technology/46-salinity-gradient⟩. [accessed 19.06.13].
[56] Ngai YY, Elimelech M. Thermodynamic and energy efficiency analysis of power generation from natural salinity gradients by pressure retarded osmosis. Environ Sci Technol 2012;46(9):5230–9.
[57] Aung HN, Myanmar's Ocean Renewable Energy Information/Data, Singapore; 2013.
[58] Ocean Energy Technology Overview, US Department of Energy, [Online]. Available: ⟨http://www.nrel.gov/docs/fy09osti/44200.pdf⟩. [accessed 18.06.13].
[59] Republic of the Philippines, 2012. [Online]. Available: ⟨http://www.reegle.info/policy-and-regulatory-overviews/PH⟩. [accessed 13.06.13].
[60] Department of Energy Philippines, Ocean Wave, 2003. [Online]. Available: ⟨http://www.doe.gov.ph/renewable-energy-res/resource-maps/279-ocean-wave⟩. [accessed 4.09.13].
[61] Australian Institute of Energy, Fact Sheet 10: Tidal Energy, [Online]. Available: ⟨http://www.aie.org.au/AIE/Documents/FS10_TIDAL_ENERGY.pdf⟩. [accessed 4.09.13].
[62] Abundo M. Current status of ocean renewable energy in the philippines. Jeju Island: Asian Wave and Tidal Conference; 2012.
[63] Energy Research Institute at National University of Singapore, [Online]. Available: ⟨http://www.ntu.edu.sg/Pages/home.aspx⟩. [accessed 5.09.13].
[64] Hann-Ocean, Hann-Ocean's WEC pilot project – Drakoo-B0016 array launched into Tuas View Sea in Singapore, Hann-Ocean, 19 August 2013. [Online]. Available: ⟨http://www.hann-ocean.com/drakoo-b0016-array-launched-tuas-view-sea-singapore/⟩. [accessed 3.09.13].
[65] Tropical Marine Institute at National University of Singapore, [Online]. Available: ⟨http://www.tmsi.nus.edu.sg/⟩. [accessed 5.09.13].
[66] Abundo ME, Assessment of Potential Tidal In-Stream Energy Sites in Singapore. In: Proceedings of the 1st Asian Wave and Tidal Energy Conference, Jeju Island; 2012.
[67] Fugro OCEANOR, [Online]. Available: ⟨http://www.oceanor.no⟩. [accessed 18.06.13].
[68] Changloy P. Research trend on renewable energy biomass energy and small scale hydropower for Thailand. Bangkok: King: Mongkut's Univeristy of Technology Thonburi; 2003.
[69] Wattanachivien APK, Interviewee, Ocean Energy Potential in Thailand. [Interview]. 17 Jan 2013.
[70] King Mongkut's University of Technology Thonburi, [Online]. Available: ⟨http://www2.kmutt.ac.th/en_index.aspx⟩. [accessed 5.09.13].
[71] Chaiwat D, Interviewee, Ocean Renewable Energy in Thailand. [Interview]. May 2014.
[72] Report on Brunei Darussalam, Reegle, [Online]. Available: ⟨http://www.reegle.info/policy-and-regulatory-overviews/BN. [accessed 5.06.13].
[73] Cambodia Country Situation, Energypedia, [Online]. Available: ⟨https://energypedia.info/wiki/Cambodia_Energy_Situation⟩. [accessed 19.06.13].
[74] Economic Research Institute for ASEAN and East Asia, Energy Integraton in East Asia, August 2013. [Online]. Available: ⟨http://www.eria.org/RPR-2012-26.pdf⟩. [accessed 1.07.14].
[75] Mukhtasor I and Firdaus AM, Ocean Energy in Indonesia: Policy, Technology, Market and Institutional Development, [Online]. Available: ⟨http://wreeec2011bali.com/uploads/files/Presentation%20Prof%20Mukhtasor.pdf⟩. [accessed 7.06.13].
[76] Azahari I. The policy of ocean energy development for electricity in Indonesia. Indonesia: World Renewable Energy Congress-Indonesia, Ministry of Energy and Mineral Resources; 2011.
[77] Indonesia Ocean Energy Association, Ocean Renewable Energy Potential in Indonesia, Jakarta; 2013.
[78] Renewable Energy Development Strategy in Lao PDR, [Online]. Available: ⟨http://www.lao-ire.org/data/documents/data_research/general/LIRE-Renewable_Energy_Development_Strategy_in_Lao_PDR.pdf⟩. [accessed 19.06.13].
[79] Mandelli S, Mereu R. Distributed generation for access to electricity: "Off-Main-Grid" Systems from home-based to microgrid, in renewable energy for unleashing sustainable development. Switzerland: Springer International Publishing; 2013; 75–97.
[80] National Priorities on Energy Efficiency and Conservation in Myanmar, National Commission for Environmental Affairs, Ministry of Forestry, Myanmar, 4–5 May 2011. [Online]. Available: ⟨http://www.unep.org/climate

change/mitigation/sean-cc/Portals/141/doc_resources/4th_Regional_Network_meeting/S6_Myanmar.pdf〉. [accessed 19.06.13].
[81] Natural Resource Aspects of Sustainable Developmnt in Myanmar, [Online]. Available: 〈http://www.un.org/esa/agenda21/natlinfo/countr/myanmar/natur.htm〉. [accessed 19 .06.13].
[82] New Energy Architecure: Myanmar, World Economic Forum, [Online]. Available: 〈http://www3.weforum.org/docs/IP/2013/EN/WEF_New_Energy_Architecture_Myanmar.pdf〉. [accessed 19 .06.13].
[83] Earth Renewable Energy Co. Ltd, Off-Grid Rural Electrification and Solar Home System in Myanmar, 1–2 November 2012. [Online]. Available:. 〈http://www.gms-sef.org/docs/workshops/National/myanmar%20ppt/day%202/S6.3%20Min%20Earth.pdf〉. [accessed 19.06.13].
[84] Philippine Council for Industry and Energy Research and Development, "Alternative Energy S&T Roadmap: "Science and Technology Roadmap: Regional Roles and Perspectives"," Manila.
[85] ERIA, Analysis on Energy Saving Potential in East Asia, June 2013. [Online]. Available: 〈http://www.eria.org/RPR-FY2012-19.pdf#page=202〉. [accessed 1.07.14].
[86] National Climate Change Secretariat (NCCS), Prime Minister's Office (SG), "Mitigation Measures," [Online]. Available: 〈http://app.nccs.gov.sg/page.aspx?pageid=83〉. [accessed 5.09.13].
[87] National Climate Change Secretariat (NCCS), "The National Climate Change Strategy 2012," [Online]. Available: 〈http://app.nccs.gov.sg/data/resources/docs/Documents/NCCS-2012.pdf〉. [accessed 5.09.13].
[88] Nanyang Technological University, "NTU puts wind in the sails for ocean energy research," Nanyang Technological University, 7 October 2011. [Online]. Available: http://news.ntu.edu.sg/pages/newsdetail.aspx?URL=http://news.ntu.edu.sg/news/Pages/NR2011_Oct7.aspx&Guid=6bdc065c-1b63-48ae-81fd-b0598ac2d691&Category=@NTU. [accessed 22.07.13].
[89] Wong YS. Development of Renewable Energy in Singapore, September 2009. [Online]. Available: 〈http://esi.nus.edu.sg/docs/esi-bulletins/esi-bulletin-vol-2-issue-2-sept-2009.pdf〉. [accessed 23.07.13].
[90] EMEC, Press Release: EMEC to Support Development of Marine Energy Test Site in Singapore," September 2013. [Online]. Available: 〈http://www.emec.org.uk/press-release-emec-to-support-development-of-marine-energy-test-site-in-singapore/〉. [accessed 1.07.14].
[91] National Research Foundation Singapore, "Energy Innovation Research Program (EIRP) Request for Proposals," 2013. [Online]. Available: 〈https://rita.nrf.gov.sg/ewi/EIRP_04/Guidelines%20and%20Templates/EIRP%20Fourth%20Call%20Document%20-%20Clean%20Energy%20Systems%20(21%20May%202013).pdf〉. [accessed 1.07.14].
[92] The Renewable, Alternative Energy Plan for 25 Percent in 10 Years (AEDP 2012-2021), [Online]. Available: 〈http://www.dede.go.th/dede/images/stories/dede_aedp_2012_2021.pdf〉. [accessed 19.06.13].
[93] Tongsopit S, Greacen C. Thailand's Renewable Energy Policy: FiTs and Opportunities for International Support, 2001. [Online]. Available: 〈http://www.palangthai.org/docs/ThailandFiTtongsopit&greacen.pdf〉. [accessed 5.06.13].
[94] Pham L. Current status of Vietnam Ocean renewable energy. Singapore: Southeast Asian Collaboration for Ocean Renewable Energy; 2013.
[95] Hammar L, et al. Renewable ocean energy in the Western Indian Ocean. Renew Sustain Energy Rev 2012;16(7):4938–50.
[96] REN21, Renewables 2013 Global Status, REN21; 2013.
[97] Ocean Energy Systems, OES Annual Report 2013, OES Secretariat, Portugal; 2013.
[98] Nugroho H. ASEAN Energy Cooperation: Facts and Challenges, The Jakarta Post, [Online]. Available: 〈http://www.thejakartapost.com/news/2011/05/19/asean-energy-cooperation-facts-and-challenges.html〉. [accessed 19.06.13].
[99] Lan YW. Issues and Challenges outlined for the ASEAN electricity market, [Online]. Available: 〈http://siew.sg/energy-perspectives/siew-2012/issues-and-challenges-outlined-asean-electricity-market〉. [accessed 19.06.13].
[100] OpenEI, Marine and HydMlarokinetic Technology Database, [Online]. Available: 〈http://en.openei.org/wiki/Marine_and_Hydrokinetic_Technology_Database〉. [accessed 1.07.14].